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Essays in Development Economics: Migration and Identity in China

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Contents

Introduction

Human behaviors are usually affected by social environment and policies or rules imposed by the governors. Nowadays we observe an increase in interactions between different communities around the world, partly as a result of transportation development and economic integration. Identity as a product of social environment becomes the link or tool for cooperation and confrontation in these interactions. Migration shaped by policies or rules also attracts increasing attention for the opportunities, problems, and conflicts that it brings to different areas involved. It is thus important to understand how identity affects group interactions and how migration is affected by policies or rules. What researchers often neglect is that the policy or regulation impact can be shaped by multiple interacted channels at the same time.

For Chapter 1, titled "*Favoring your in-group can harm both them and you: ethnicity and public goods provision in China*", with my coauthors César Mantilla, Charlotte Wang, Donghui Yang, and Suping Shen, and Paul Seabright, we conducted lab-in-the-field experiments in Xishuangbanna, home to 25 out of 55 official Chinese ethnic minorities. We find that participants in trust games send around 15% more to partners they know to be co-ethnics than to those whose ethnicity they do not know. Receivers' behavior is determined by amounts received and not by perceived ethnicity. In line with the previous literature we find that subjects contribute more to public goods in ethnically homogeneous groups than in mixed groups. We find evidence for a new explanation that is not due to different intrinsic preferences for cooperation with ingroup and outgroup members. Instead, subjects' willingness to punish in-group members for free-riding is reduced when out-group members are present. This leads to lower contributions and net earnings in mixed groups. Thus favoritism towards co-ethnics can hurt both those engaging in favoritism and those being favored.

In Chapter 2, titled "*Marriage, Migration, and Migration Policy: Evidence from Hukou Reform in China*", I focus on two questions. First, how much do marriage prospects affect individual's migration choices? Second, how does marriage shape the effectiveness of migration policies? To study these questions, I develop a dynamic migration and marriage model where

migration policies regulate migrant access to local benefits. I show that merit-based migration policies have very limited effects on migrant composition if we take into account the marital gains and spouse adjustments to policies. Empirically, I estimate the model using Chinese data. I first show that intermarriage opportunities drive 10% of migration of singles aged 20-35 in 2000. I then show that if migrants could obtain local hukou right after migration, the migrant inflows of young people to large cities would increase by 2 times in 2000. Neglecting the indirect policy impact through marriage markets, we would underestimate the migration of men by about 30% and of women by 40% in large cities.

In In Chapter 3, titled "*Revealed or Forced: Migration Response to Pollution Disclosure*", co-authored with Zichen Deng, we examine the impact of pollution information disclosure on individual location responses to air pollution. The inference of information value can be misleading if we attribute the behavioral changes after information disclosure only to misperception. This paper studies the impact of an influential national air quality information disclosure program in China in 2013-2015 on individual migration responses to air pollution. Specifically, we exploit the roll-out of this program and the variation in regional initial pollution. The migration measures are obtained from detailed individual migration history in the Population Census 2015. We demonstrate that the resulting migration responses are not only due to changed perception of health risk. By exploiting mayors' promotion incentives, we show that the change of economic opportunities given rising environmental regulation contributes to 8.3% of the observed migration responses.

Chapter 1

Favoring your in-group can harm both them and you: ethnicity and public goods provision in China (joint with César Mantilla, Charlotte Wang, Donghui Yang, and Suping Shen, and Paul Seabright)[1]

1.1 Introduction

How much do people allow the ethnic identity of others to influence their decisions to trust and cooperate with them? This project reports an experimental study of trust relations between and among members of ethnic minorities in South-West China. In May and June 2016, 31 experimental sessions were conducted with 576 subjects in five locations in Xishuangbanna, Yunnan Province. The region is home to 25 out of 55 official Chinese ethnic minorities, most of whom retain distinctive linguistic, cultural and vestimentary markers of ethnic identity. The purpose of the study was to discover whether ethnic identity influences a range of behaviors relevant to establishing cooperation: willingness to trust unknown others and to reciprocate their trust, willingness to contribute to public goods, and willingness to engage in costly punishment aimed at enforcing cooperative norms.

It is well known that human interactions are characterized by a demand for environmental cues (Snyder and Ickes, 1985). Among these cues, the capacity to establish boundaries defining an "in-group" and an "out-group" has been important throughout history in resource allocation problems involving public goods provision (Banerjee, Iyer and Somanathan, 2005), team production (Björkman and Svensson, 2010; Kato and Shu, 2016) and warfare (Bowles, 2009).

[1] This chapter is based on **?** published at the Journal of Economic Behavior and Organization. Paul Seabright acknowledges IAST funding from the French National Research Agency (ANR) under the Investments for the Future (Investissements d'Avenir) program, grant ANR-17-EURE-0010. The authors would like to thank Xing Yang, Xingyu Chen, and Yi Zhao for outstanding research assistance in Yunnan.

Heterogeneity within the group has often been found to undermine the attainment of socially efficient outcomes (Easterly and Levine, 1997; Cardenas, 2003; Zelmer, 2003; Alesina and Ferrara, 2005). In the case of public goods provision a very salient feature is ethnicity, one that has been found by Miguel and Gugerty (2005) to be important for the provision of education and health public services in Kenya.

In an influential study, Habyarimana et al. (2007) explore three possible mechanisms explaining the under-provision of public goods in the presence of ethnic diversity: preferences, strategy selection and technology. The preference mechanism may occur either through differences in the type of public goods that each group wants to be provided, as in the case of impure public goods (Cornes and Sandler, 1994), or through different intrinsic preferences of subjects for cooperation with in-group and out-group members. Strategy selection is very similar to what Arrow et al. (1973) defined as statistical discrimination. That is, in the absence of more reliable information, individuals may use observable characteristics (such as ethnicity) to infer a partner's expected behavior in a potential interaction. Finally, the technology mechanism refers to the greater ease with which subjects can find co-ethnics in the social network, enabling better coordination as well as more effective monitoring and punishment of free-riders.

Yunnan Province in China is a particularly good setting in which to explore such hypotheses, since different ethnic groups have lived in close proximity in this province for a long time without a major history of inter-ethnic violence, of the kind that would significantly complicate the study of inter-ethnic cooperation between, say, Hindus and Muslims in India, Sinhalese and Tamils in Sri Lanka, Sunnis and Shias in the Middle East. At the same time the inter-ethnic differences we study are not simply ones elicited in the laboratory but are real pre-existent differences of which all participants are aware and with unquestionable ecological validity. Our findings are therefore of interest not just for China but for the study of ethnic differences throughout the world - they can be interpreted as an indicator of the way ethnicity frames cooperative interactions even in the absence of significant historical enmities.

Our own study finds results that are broadly consistent with those of Habyarimana et al. (2007) but go substantially beyond them. We conducted a computerized lab in the field experiment comprising two blocks. Block 1 consists of multiple trials of a trust game with an underlying matching algorithm controlling the in-group or out-group information provided about the counterpart. Block 2 consists of a repeated public goods game with punishment in which the matching algorithm creates ethnically homogeneous and mixed groups. We document a reduced willingness of subjects to punish co-ethnics for free-riding when outsiders are present, a

phenomenon that, when rationally anticipated by others, leads to lower levels of public good contribution in ethnically mixed groups.

Our findings are that first movers in the trust game do use ethnic information to judge whether to trust others, suggesting a significant role for strategy selection. Individuals who know that they share the same ethnic identity with the receiver are willing to make a transfer around 15% larger to the partner than to partners whose identity they do not know. However, there is great variation among ethnic groups in this regard, with the national majority Han showing no favoritism, and one group (the Hani) whose members actually send slightly less to their own group than to others (though the difference between amounts sent to their co-ethnics and to others is not statistically significant). The failure of the Hani to show the same favoritism to co-ethnics as the other groups suggests their behavior may be based on a rational anticipation of the fact that Hani members are on average less trustworthy than others. This would be consistent with strategy selection but not with the preference mechanism, in confirmation of the findings of Habyarimana et al.. This interpretation is corroborated by the fact that amounts sent by second movers respond strongly to amounts received but not otherwise to information about shared ethnicity with the partner.

In the public goods game, individuals display a lower willingness to punish members of their own ethnicity (their "in-group") when in the presence of other ethnicities (their "out-group"). Specifically, when they play in mixed-ethnicity groups, they are more than 5 percentage points less willing to punish in-group members for free-riding than to punish out-group members, most of that representing a reduction relative to their willingness to punish in-group members when there are no out-group members present. This difference in punishment behavior in homogeneous versus mixed groups is crucial to explaining differences in public goods contributions. It seems that there is an element of preserving in-group solidarity in the presence of out-group members, which has been shown experimentally to be an important consideration in economic experiments in China (Eriksson, Mao and Villeval, 2016). This partiality towards in-group members, as anticipated by players, has a paradoxical impact on levels of contribution in the public goods game. Players contribute less in mixed groups where their own ethnicity is in a majority, apparently anticipating a lower likelihood of punishment if they free ride.

Putting together the latter two results, we provide evidence in favor of one additional mechanism undermining public goods provision in the presence of ethnic diversity. That is, in-group favoritism erodes the credibility of punishment institutions. Alexander and Christia (2011) provide evidence that ethnic diversity contributes to under-investment in public goods principally when the institutional context leads punishment mechanisms to lose their credibility. Our results

can be considered as identifying and characterizing such an institutional context.

The effect of inter-ethnic interactions on trust and cooperation has been explored in China in a laboratory setting. Zhang, Zhang and Putterman (2019) provide evidence of lower levels of trust and cooperation between Uyghur and Han college students when they interact with members of the other ethnicity. Morton, Ou and Qin (2019) show that making salient ethnic identity between Han and Tibetan students leads to worse outcomes in a voting coordination game, compared to minimal group identities. We contribute to this literature by exploring inter-ethnic interactions outside the laboratory.

In our view our results can help to explain a number of general features of socially inefficient behavior, such as corruption. It is a commonplace that people complain about corruption on the part of the relatives and entourage of politicians and not just about the behavior of the politicians themselves. This may reflect as much a diminished willingness on the part of the politically powerful to discipline corrupt behavior by their in-group, as any conscious encouragement of venality on their part.

A similar phenomenon may explain why minority individuals feel uncomfortable and unsafe when in city neighborhoods dominated by another ethnic group. It may be not so much that they fear greater intrinsic hostility by the majority, rather as a reduced willingness on the part of majority individuals to punish opportunistic violence by their co-ethnics.

Our paper is structured as follows. Section 2 discusses our hypotheses in detail in the light of the literature on cooperation and ethnicity. Section 3 describes the experimental set-up and section 4 the sampling procedure. Section 5 reports the results of the trust game. Section 6 does the same for the public goods game. Section 7 discusses more general implications of the findings. Section 8 concludes.

1.2 Experimental contributions on the under-provision of public goods: a review

The previous literature has sought to distinguish preference-based explanations for the influence of ethnic identity on cooperative behavior from those that appeal to strategy selection and punishment mechanisms. We survey each of these phenomena in turn.

1.2.1 Strategy selection and the trust game

The selection mechanism has its roots in the definition of statistical discrimination (Arrow et al., 1973), which is the use of observable characteristics of an individual to infer an expected behavior and respond appropriately to it. This is different from what Becker (1957) had previously defined as taste-based discrimination, in which there is a prejudice against interacting with subjects who have particular traits.

Fershtman and Gneezy (2001) disentangled statistical discrimination from taste-based discrimination using a trust game and a modified dictator game, in which the receiver keeps the triple of the transferred amount. Statistical discrimination can be disentangled from taste-based discrimination because the sender expects an action from the receiver in the trust game but not in the dictator game. Fershtman and Gneezy find that discrimination between Ashkenazic Jews and Eastern Jews in the trust game is statistical and not taste-based. This experimental design has gained popularity and has been used to test for both ethnic discrimination (Willinger et al., 2003; Fershtman, Gneezy and Verboven, 2005; Buchan, Johnson and Croson, 2006) and religious discrimination (Karlan, 2005; Tan and Vogel, 2008; Johansson-Stenman, Mahmud and Martinsson, 2009; Auriol et al., 2017)

Gupta et al. (2018) argue that in some of the previous evidence it is not possible to disentangle religion from the lower economic status derived from being part of a minority group. They execute a trust game in the border between West Bengal and Bangladesh to disentangle such effects: Hindus are the majority in West Bengal but the minority in Bangladesh, while Muslims are the minority in West Bengal but the majority in Bangladesh. Gupta et al. find that it is economic status rather than religion that dictates behavior in a trust game.

Identity priming has been shown to affect intellectual performance (Hoff and Pandey, 2014; Afridi, Li and Ren, 2015), behavior in coordination and cooperation games (Chen et al., 2014; Jiang and Li, 2019), social preferences (Chen and Li, 2009) and discrimination against the out-group (Amira, Wright and Goya-Tocchetto, 2019; Bauer et al., 2018). However, discrimination harming the out-group does not necessarily coexist with in-group favoritism (De Dreu et al., 2010).

1.2.2 Punishment in the public goods game

Punishment institutions have shown to be efficiency enhancing in social dilemmas if the number of interactions is sufficiently large, and if feedback does not lead to a rapid update of expectations about others' contributions (Fehr and Fischbacher, 2004; Gächter, Renner and Sefton, 2008; Nikiforakis and Normann, 2008; Nikiforakis, 2010). Although punishment is costly for both the punisher and the punished, the mere threat tends to have a deterrent effect preventing the trespass of social norms. However, the institutional context is crucial, and there are substantial differences across cultures and countries with respect to the effectiveness of the punishment mechanism (Alexander and Christia, 2011). The punishment institution may also bring "by-products" that decrease its legitimacy. There is evidence that anti-social punishment and counter-punishment could also emerge (Nikiforakis, 2008; Balafoutas, Nikiforakis and Rockenbach, 2014), in particular within societies with weak norms of civic cooperation (Herrmann, Thöni and Gächter, 2008). Similarly, when in-group and out-group payoffs are negative and strongly correlated, punishment tends to be efficiency decreasing (Abbink et al., 2010).

For studies conducted in China, the effect of punishment on efficiency is mixed. On the one hand, Wu et al. (2009) report that punishment decreased cooperation rates in a two-player Prisoner's Dilemma. On the other hand, Song and Zhou (2011) and Xu et al. (2013) report efficiency increasing effects of punishment in public good games with heterogeneous marginal per capita returns (MPCR) and different group sizes, respectively. Finally, Li and Yang (2017) find laboratory evidence that subjects punish out-group members differently when they know that group identities will be revealed to punishees. The pool of subjects, in all four cases, consists of university students. In stark contrast, our study involves a rural, non-student population from South-West China.

1.3 Experimental design

1.3.1 Overall design

The experiment was programmed and executed using oTree (Chen, Schonger and Wickens, 2016). Participants engage in real-time interactions by making their decisions using tablets. The use of oTree allows us to involve populations who not only live far away from academic experimental laboratories, but also have no familiarity with computers and might be easily be intimidated by a laboratory.

Each session was made up of participants from two different ethnicities (the sampling procedure is explained in detail in Section 1.4). At the beginning of the session participants were asked to state with which of the ethnicities they felt more closely identified. This information was employed by a matching algorithm determining the interactions in Blocks 1 and 2, which are described in detail below. We sorted the participants by ethnicity and assigned them random identifiers. In the trust game, the first several participants of one ethnicity and the last several participants of the other played as senders. In each round, we matched some participants with the same ethnicity and the rest with the other ethnicity. In the public goods game, the first four participants of one ethnicity and the last four of the other were allocated to homogeneous groups. The rest of the participants were allocated to mixed groups. The fact that the randomization of both games was based on the same sorting algorithm resulted in a correlation between being sender/receiver and being in ethnically homogeneous/mixed groups. We did not notice this correlation until after the experiment, but as we explain below it reduces the statistical power of our tests that aim to discriminate between ethnic composition and prior trust game experience in explaining outcomes in the public goods game.

We also collected information about their religious affiliation using the same procedure. Although this information was not employed in the matching algorithm, it was employed in Block 1 as an alternative label to for the purposes of evoking in-group and out-group affiliations. We describe the results from disclosing religious affiliation in the trust game as an additional exercise.

In our experimental design we combine the use of a trust game (Block 1) followed by a public goods game with punishment (Block 2). Trust, and more generally social capital, are predictors of contributions in public goods games when using self-reported or incentivized trust measures (Anderson, Mellor and Milyo, 2004; Thöni, Tyran and Wengström, 2012; Kocher et al., 2015), so we could reasonably expect to find some correlation between how subjects played in one game and how they played in the other, a point we discuss in presenting the results below. We played the trust game before the public goods game, as we wanted to rule out the possibility that the experience of punishment in the public goods game might impact decisions in the trust game. However, this meant that we could not prevent the experience of the trust game from influencing behavior in the public goods game. This was a particular risk given that we decided to disclose the earnings of the trust game at the end of Block 1, to foster participant's attention and trust in the experimenters for Block 2, given the challenging field setting of our study. In fact, we see that behavior in the trust game is indeed significantly predictive of public goods game contributions, as we would expect if both types of experiments capture characteristics related to both trustingness and trustworthiness. We would not expect it to be predictive of punishment

behavior, which responds to the previous behavior of other subjects - and indeed we find that it is not. In addition, including trust game behavior has almost no impact on the main coefficients in the punishment regressions, and although it reduces some of the coefficients in the contribution regressions they remain significant at conventional levels.

1.3.2 Block 1: Trust game

In this pairwise interaction setting we define the first mover as the "sender" and the second mover as the "receiver." The sender is endowed with $e = 50$ points (i.e., tokens) and must choose an amount $x \in [0, 5, 10, \ldots, 50]$ to transfer to the receiver, who has a null endowment.[2] The sender knows that for each transferred unit his/her partner will receive the triple. The receiver gets a transfer of $3x$ and then he/she decides how much to send back to the sender. The receiver is free to choose any amount $y \in [0, 5, 10, \ldots, 3x]$ to transfer.

The sender knows that the the receiver can transfer back any amount between 0 and $3x$. However, in the one-shot game with pure selfish preferences the sender anticipates that the receiver will choose $y = 0$ regardless of his/her initial transfer x. Therefore, the sender will choose $x = 0$. The socially efficient solution, on the other hand, is that the sender chooses $x = e$ and maximizes the pie of $3e$ that will be split by the receiver.

The popularity of the trust game arises from the fact that it recreates the strategic complexity of incomplete contracts. The sender is aware that positive transfers are efficiency-enhancing, but he/she has no means to guarantee the appropriation of a share of the efficiency gains. The receiver, on the other hand, is equally unable to signal his/her willingness to send back a positive fraction of the received amount. Fershtman and Gneezy (2001) show that information allowing the categorization of the partner is employed as a signal affecting decision making. Here, our design aims at capturing the behavioral differences in the trust game depending on whether the partner belongs they refer to an insider or to an outsider.

Our experimental design comprises five interactions per player in the trust game, each one with a different level of information:

[2] Our decision to give a null endowment to the receiver is common in the literature, though it differs from the procedure in the trust game as introduced by Berg, Dickhaut and McCabe (1995). In that first study the sender and receiver start with the same endowment. Our procedure is particularly common in field settings, and seems to us easier to understand in such settings.

- Interaction 1: random matching - no information
- Interaction 2: in-group matching - ethnicity disclosed
- Interaction 3: in-group matching - religious affiliation disclosed
- Interaction 4: out-group matching - ethnicity disclosed
- Interaction 5: out-group matching - religious affiliation disclosed

We have within-subject variation on the partner's disclosed information {*ethnicity*, *religion*} and social distance {*in-group*, *out-group*}. However, the participants' role, sender or receiver, was fixed for the five interactions. The disclosed information was presented as follows: "Participant A/B identifies with the ☐ ethnic group" and "Participant A/B identifies with the ☐ religion." Here, "Participant A" refers to the sender and "Participant B" refers to the receiver (see the full protocol in the supplementary material). Besides, at the beginning of the block we made participants aware that we might give them some additional information about their partners.

We were interested in the transfers made by the sender, and how they varied based on the receiver's disclosed information; and also on the transfers made by the receiver, though the available information for the latter included the transfer x made by the sender. An alternative data collection strategy would have been to use the strategy method for the receivers (Ashraf, Bohnet and Piankov, 2006; Brandts and Charness, 2011). That is, to ask for their transfers, contingent on every potential choice of the sender. We decided against this alternative given the larger set of choices that receivers would have needed to make (five choices in each one of the five trust games), a much more serious constraint for a lab-in-the-field experiment with subjects unfamiliar with such experiments, and even with the use of computers.

We also randomized the order of presentation to control for order effects at the between-subject level. In half of the sessions subjects are matched first with their in-group (interactions 2 and 3 correspond to rounds 2 and 3, respectively) and then with their out-group (interactions 4 and 5 correspond to rounds 4 and 5, respectively). In the other half of the sessions subjects are first matched with their out-group.

For the payment of this block of the game we randomly selected one of the five rounds and paid at the end of the whole experiment. Senders did not receive any feedback regarding the receivers' choices until the end of the block. Therefore, we can assume that the senders' decisions were independent across rounds. This is not necessarily the case for receivers, who

were informed in each round of the transfer x made by their partner.

1.3.3 Block 2: Public goods game

An additional advantage of conducting the lab-in-the-field experiment using oTree is the possibility to implement in Block 2 a repeated public goods game with punishment, an experimental setting typically belonging to the laboratory.

This game involves four symmetric players per group, who repeatedly interact for five rounds. Each round comprises the contribution stage and the punishment stage. In the contribution stage each participant is endowed with 10 points that can be invested in a private or a group account. The return of the private account is normalized to 1 and only benefits the player itself. In the group account, on the other hand, each invested point yields a return of 2 to be equally divided among group members. Hence, the individual's return for an invested point in the group account is 0.5, half of its return in the private account. Therefore, in the one-shot game subjects with selfish preferences do not have an incentive to invest in the group account even if it is efficient.

In the second stage participants decide whether they want to allocate a costly disapproval card to each one of the group members.[3] Each disapproval card costs 2 points for the punisher and decreases the earnings of the punished group member by 5 points. Prior to the binary punishment decision, the participants are informed about the individual contributions of the other group members and their ethnicity. After the punishment stage participants are informed on how many disapproval cards were assigned to them, but they do not know the punishers' identity. The payment for participant i after the two stages of the round is given by:

$$\pi_i = (10 - c_i) + \frac{1}{2}\sum_{j}^{4} c_j - 2\sum_{j \neq i} p_{ij} - 5\sum_{j \neq i} p_{ji} \tag{1.1}$$

Where p_{ij} represents the punishment cards that i assigned to the other j group members and p_{ji} are the punishment cards that the other j group members assigned to i. As punishment is individually costly, in the one-shot game purely self-interested subjects would undertake zero expenditure on punishing other group members.

[3] Standard public goods games consider multiple punishment levels instead of binary decisions. The simplification proposed in our design aims towards a clearer protocol after considering the low educational attainment in the targeted population. We use the term "disapproval card" instead of "punishment card" to reduce experimenter demand for punishment. For instance, Nikiforakis (2008) describes the punishment decision to participants as a "distribution of points."

The matching protocol introduces between-subject variation in group composition that remains fixed over the five rounds. In every session two homogeneous groups (4+0) are created, one per ethnicity. The remaining subjects are matched in mixed groups. Mixed groups are balanced (2+2) in sessions with equal number of participants per ethnicity. Otherwise there are mixed groups (3+1). The latter case corresponds only to 7 percent of our observations. The random assignment of participants between homogeneous and mixed groups can be checked in Table A.1.[4]

It might have happened that group formation by itself created an additional sense of belonging (Tajfel et al., 1971), in addition to the ethnic identity. Nonetheless, random assignment to minimal groups tend to have less strong effects compared to group assignment involving real social interactions (Goette, Huffman and Meier, 2012). We believe that identiy effect from minimal groups are a small concern in our case. If they did occur, they would have created more cohesiveness in our ethnically mixed groups, yielding a lower-bound to our estimates.

1.4 Research site and sampling procedure

China has 56 ethnic groups, the dominant Han plus 55 minorities. As of 2010, the combined population of minority groups stood at about 115 million, 8.5% of the total mainland population.[5] Geographically, the ethnic minorities in mainland China are much more rural than urban, although the national population is slightly more urban (54%) than rural (46%). They are specially concentrated in the North-East (Koreans and Manchus), North-West (Uighurs, Tibetans and Hui) and South-West of the country (Zhuang, Dai, Hui, Hani and Bai, among others). These regions are less developed and urbanized in comparison to the Eastern Coast and the Central provinces. Yunnan province in South-West China is where the density of population for the minority ethnic groups is the highest. 34% of the provincial inhabitants belong to 25 different minorities, 15 of which have at least 80% of their population in Yunnan.

This study was conducted in Xishuangbanna (Banna hereafter), an autonomous prefecture of the Dai minority, in the south of Yunnan Province, where the Buddhism is the main religion.

[4] Demographics and religious affiliation are balanced. Ethnicity, on the other hand, is unbalanced with a greater proportion of Dai in homogeneous than in mixed groups. The greater proportion of Dai participants in homogeneous groups is the consequence of having two sessions in which all participants were Dai (with variation in religious affiliation).

[5] From the 6th national population Census undertaken in 2010.

Banna extends over 19,600km^2 and is bordered by Laos and Myanmar. Its total population is around 1.2 million inhabitants, among which around 78% correspond to ethnic minorities. The most populous ethnicities in Banna are the Dai, the Han, and the Hani (with 33%, 23%, and 21% of the whole population).[6] These three most reprensentative ethnicities were included in our sample, in addition to the Bulang (4.19% of the whole regional population).[7] We choose these four ethnicities for three reasons. First, the Han are the national majority group, and the Dai are the regional majority group. Second, the Bulang share the same religion with the Dai, helping us to control for the effect of religion. Third, we chose the Hani because we needed enough village groups within reasonable distance (fifteen-minute daily transportation) to the sites of our experiment, and the local leaders were willing to help us with recruitment. The Hani also bring variation in religious beliefs.

The Dai, the Hani and the Bulang have their own languages and distinct cultural identities. However Mandarin Chinese can be understood almost everywhere even by those for whom it is not the language they use every day. The religious affiliations of these four minorities are closely linked to their ethnic identity. The Dai's culture is strongly based on its rather homogeneous religious belief in Theravada Buddhism, although there are still a few Dai villages where people are Christian exceptionally. The Bulang minority's religious beliefs are a mixture of Buddhism and other original religions. The Hani are mainly characterized by adherence to folk religion. The Han are mostly atheist, as elsewhere in the country, even if a few of them are Buddhists or Christians or practice other religions. The Han participants in our study are either atheist or Christian.

Thirty-one sessions of trust games and public good games were run with 576 participants in different areas of Banna between May and June, 2016. This period happened to coincide with the local elections. The experiment was conducted in a city (Jinghong) and seven village committees in four towns (Daluo, Menghun, Gasa, and Dadugang) where different ethnicities cohabit there. Figure 1.1 displays, in red circles, the five locations where the sessions took place. In the administrative division in China, a village committee (administrative village) is in charge of several village groups (natural villages).[8] Each village committee for our experiment has 8-20 village groups, a village group has around 40-100 households, and each household has on average 4-5 persons.[9] Within a village committee, village groups are geographically separated

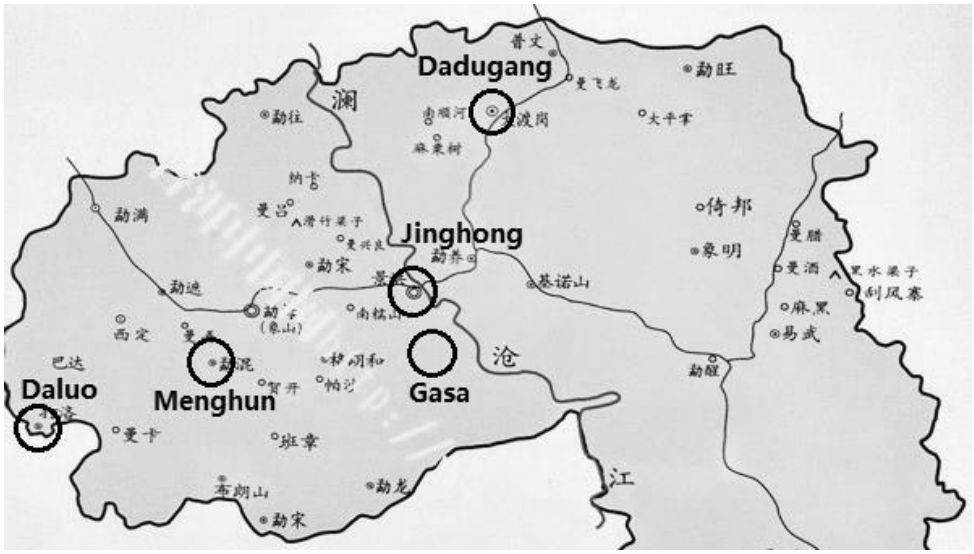
[6] According to 2019 official data published by the local government. Click for the link.

[7] From the 6th national population Census undertaken in 2010.

[8] Natural villages are ones that spontaneously and naturally exist within rural area and are not an administrative division.

[9] From http://ynszxc.gov.cn/S1/, a government website on villages in Yunnan Province.

Figure 1.1: Xishuangbanna Locations where experimental sessions took place are marked in circles.



Source: http://www.teapot.com.tw/

and autonomous, but interact with each other in social life, e.g. in schools or markets. Running the experiment in different village committees increases the representativeness of our results and reduces information transmission between sessions.

We conducted 31 sessions including four different matching configurations of ethnicities: Dai-Bulang, Dai-Han, Dai-Hani, and Bulang-Hani. Table 1.1 reports, per location, the number of sessions conducted for each combination of ethnicities and the number of participants. The implemented matching configurations, and their frequency, were subject to geographical constraints which prevented us from implementing other pairings of ethnicities (e.g., Bulang-Han sessions).[10]

In each session we aimed to recruit twenty participants, ten for each configuration. Before each session, we contacted the leaders of village committees or village groups, and requested them to contact ten participants satisfying certain ethnicity. One exception was in Manxi village committee, where we asked a Bulang women, who could send messages to around 300 Bulang at the same time using the social network Wechat. In Jinghong, we contacted the pastors to recruit Christians. In two sessions in Jinghong, we also requested the locals to find participants, and the participants were scattered in Jinghong. In case of no show-up, we asked participants, the organizers, and neighbors to find subjects available immediately, or we started running the experiment. The details of session composition are summarized in Table A.3.

[10] Table A.2 reports the distribution of religion by location.

Table 1.1: Number of sessions and subjects for each session configuration (per location).

Session Configuration	# Sessions	# Subjects
Daluo		
Dai-Bulang	5	92
Bulang-Hani	5	92
Dai-Hani	1	20
Menghun		
Dai-Hani	4	76
Gasa		
Dai-Han	2	40
Dai (Christian)-Dai (Buddhist)	1	20
Jinghong		
Dai-Han	8	148
Dadugang		
Dai-Han	5	88
Total:	31	576

A common concern regarding sampling in lab-in-the-field experiments is whether the intended anonymity created by the experimental protocol is violated due to session composition. It is possible that subjects may guess more information about their interaction partners than is provided by the experimenter because they may recognize some of those who have shown up to the session. To address this concern we constructed a variable indicating the "closeness" between any pair of players. For sessions in which subjects were told the ethnicity of the others with whom they played, the closeness is the probability that a random member of the indicated ethnicity also belongs to the same village group. We control for closeness in our explanatory regressions below, where as will be seen it is rarely significant (only once at the 10% level). We define closeness formally in Appendix A.2. To improve accuracy of our ethnic self-reports, we cross-validate using experimental records, participants' self-reported source locations, government detailed records of ethnicity composition for each village group, and information from local leaders.

The sessions were conducted with the following procedure. At the beginning of each session subjects were randomly assigned to a seat. Then, each participant received the tablet employed to conduct the experiment using oTree (Chen, Schonger and Wickens, 2016). The game instructions were orally provided before each game, with additional written support in the subject's tablet. We placed special emphasis on the privacy of each participant's decision. Hence, they were not allowed to look at each others' tablets or to communicate. Participants were also informed that, in case of questions, they could raise their hand so that one of the experimental monitors could

address the query in private. After instructions were understood, participants gave their written consent to participate. The next step for each participant was to submit in the tablet his or her own ethnicity and religious affiliation, if any. This information was used as an input for the matching protocol in the trust game and the public goods game.

We do not have much concern over information transmission between sessions, except in session 9.[11] In all the other sessions, it took time for participants to understand the rules, and a few needed extra explanations from the assistants.

Each session lasted between 100 and 120 minutes. Endowments and payments were expressed in terms of points. Participants were informed in advance of the exchange rate: one point equals 0.40 Chinese yuan (CNY). Participants were paid in cash after all the sessions finished. The total payment was on average 86 CNY, including a show-up fee of 40 CNY. The average earnings for participation were equivalent to about 12 euro at the time of the experiment.

1.5 Results: Trust game

1.5.1 Sender's behavior

In the first round, in the absence of information, the average transfer x is 19.7 points with a median of 20 points. That is, subjects transfer on average 40% of their endowment. This amount is below the mean transfer reported in Johnson and Mislin's (2011) meta-analysis. Nonetheless, previous studies conducted in China reveal similar average transfers (Johnson and Mislin, 2011). Table 1.2 provides details by treatment and ethnicity.

We focus now on understanding whether our treatments affect the sender's transferred amount. Figure 1.2 shows, for the pooled sample and for each ethnicity, the point estimates and confidence intervals for the four variables of interest. That is, the effect of disclosing the receiver's ethnicity for the cases of in-group and out-group matching. The displayed coefficients correspond to an OLS regression with the following additional controls: session fixed effects, ethnicity (for the pooled sample), religious affiliation, and two binary variables indicating whether the partner was from the same ethnicity or religious affiliation.[12] Standard errors are clustered at the participant

[11] Participants understood quickly the rules and performed well in the example question, and we were told afterwards that they already knew the rule. We chose to exclude this session from the analysis to avoid confounding effects.

[12] The indicator variable for shared ethnicity was introduced as control because the in-group treatment effects are

Table 1.2: Means and standard deviations of amounts sent by first movers in the trust game - by ethnicity and treatment.

	Amount of endowment sent (First mover)				
	No Info.	Same Ethn.	Same Relig.	Other Ethn.	Other Relig.
Bulang (N=45)	18.33± 12.11	18.00± 13.03	21.33± 15.20	21.67± 14.42	22.56± 15.69
Dai (N=85)	20.06± 12.74	22.18± 15.38	22.53± 15.31	22.06± 14.91	24.24± 14.59
Han (N=64)	22.89± 13.45	24.69± 13.97	25.23± 15.16	25.86± 15.24	25.39± 16.07
Hani (N=47)	15.21± 12.72	14.79± 10.88	14.26± 13.55	17.55± 13.35	18.72± 15.41

Note: Among 288 senders, 241 of them played at least once with a different ethnicity. The table is based on the 241 participants.

level. The regression results are reported in Table A.5.

Coefficients for the pooled sample (white circle) indicate in-group favoritism when the receiver's ethnicity (+3.3 points) is disclosed. This is a large effect, equivalent to just over 15% of the average amount transferred without information. In contrast, being matched with an out-group partner does not have a statistically significant effect for ethnicity. That is, out-group matching triggers neither favoritism nor hostility with respect to the situation with no information about the receiver.

The second finding that emerges from inspection of Figure 1.2 is that ethnic in-group favoritism is subject to considerable variation across ethnicity. Bulang and Dai transfer on average 8.5 and 6.2 additional points to their co-ethnics respectively. The Han's additional transfer of -4.4 points is not statistically significant. The Hani do not show the same favoritism to co-ethnics as the other groups, but this failure is not statistically significant after adding individual controls. As can be seen in Table A.5, column 2, the Hani send substantially and significantly less than other groups, but they do so to all receivers including their co-ethnics.

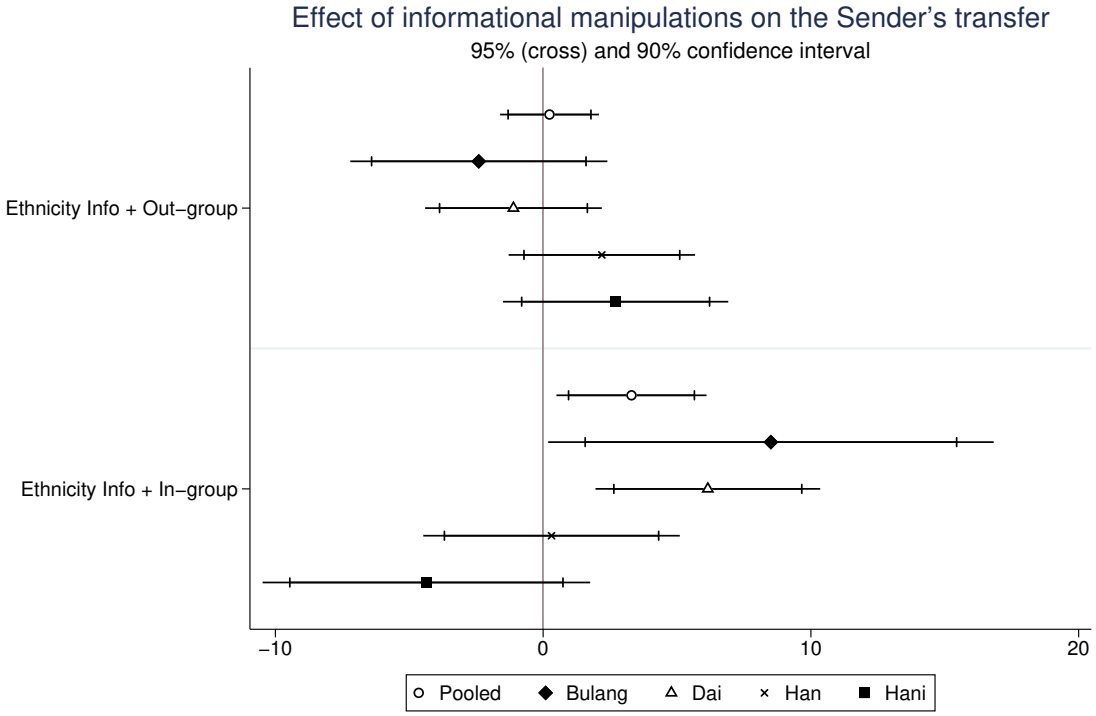
1.5.2 Receiver's behavior

For the analysis of the second mover, or receiver, our outcome of interest is the number of points transferred back to the sender $y' = y/3x$ with $x > 0$. On average receivers sent back 36% of what they received, with the median proportion being one third (33%). Table 1.3 provides details by treatment and ethnicity.

Figure 1.3 displays, for the pooled sample and for each ethnicity, the point estimates and

obtained by interacting "same ethnicity" with the disclosure of "ethnic" information.

Figure 1.2: **OLS coefficients for the treatment variables on the transfer from the sender.** The reported coefficients, for the effect of disclosing in-group and out-group ethnicity, correspond to five different estimations: a pooled regression with subjects from all ethnicities, plus one regression per ethnicity. For each point estimate is displayed the 95% (vertical line) and 90% (end of line) confidence intervals. Units are transferred points. The results are based on 241 participants who played at least once with a different ethnicity.



Note: The dependent variable is the amount sent by a sender in a round × session. The analysis is based on the participants that at least played once with a different ethnicity in all the five rounds. That is, 241 senders. Ethnicity, religion and session FE are controlled. Geographical closeness (see the precise definition in Subsection A.2 in the Appendix) and individual characteristics including age, gender, education, marital status, self-perceived relative wealth, and a dummy of being farmer are controlled. The results are in Table A.5.

Table 1.3: Means and standard deviations of amounts returned by second movers in the trust game - by ethnicity and treatment.

	Percentage of received amount sent back (Second mover)				
	No Info.	Same Ethn.	Same Relig.	Other Ethn.	Other Relig.
Bulang (N=44)	33.53± 22.10	32.14± 20.92	29.69± 21.06	32.87± 21.01	35.40± 25.29
Dai (N=130)	35.13± 23.70	38.81± 27.76	36.70± 24.83	36.40± 24.29	36.64± 23.93
Han (N=60)	43.55± 27.08	40.43± 22.86	46.17± 31.81	46.14± 26.64	46.84± 28.04
Hani (N=41)	29.14± 24.26	30.72± 25.77	43.00± 30.41	36.70± 24.29	35.38± 22.55

Note: Among 288 receivers, 275 of them played at least once with a different ethnicity. The table is based on the 275 participants.

confidence intervals for five variables of interest. In addition to the four treatment variables

involving information and in-group/out-group matching, we also report in this Figure the coefficient of the sender's transfer. The reason is that receivers were informed not only about their partners' ethnicity but also about his/her transfer x.[13] The displayed coefficients correspond to the OLS regressions reported in Table A.6. We control for session fixed effects, ethnicity (for the pooled sample), religious affiliation, individual characteristics, geographical closeness, and a binary variable indicating whether the receiver shared ethnicity with the sender. Standard errors are clustered at the participant level.

We do not find an effect for any of our treatments that is significant at conventional levels. The disclosure of the sender's ethnicity does not have a significant impact on the amount transferred back by the receiver. The amounts returned appear to be proportional to the sender's transfer: we cannot reject proportionality for the sample as a whole, and can do so only for the Hani sub-sample whose amounts returned are less than proportional. Their behavior here is entirely consistent with the behavior of the Hani in the first stage when they know themselves to be playing against their co-ethnics.

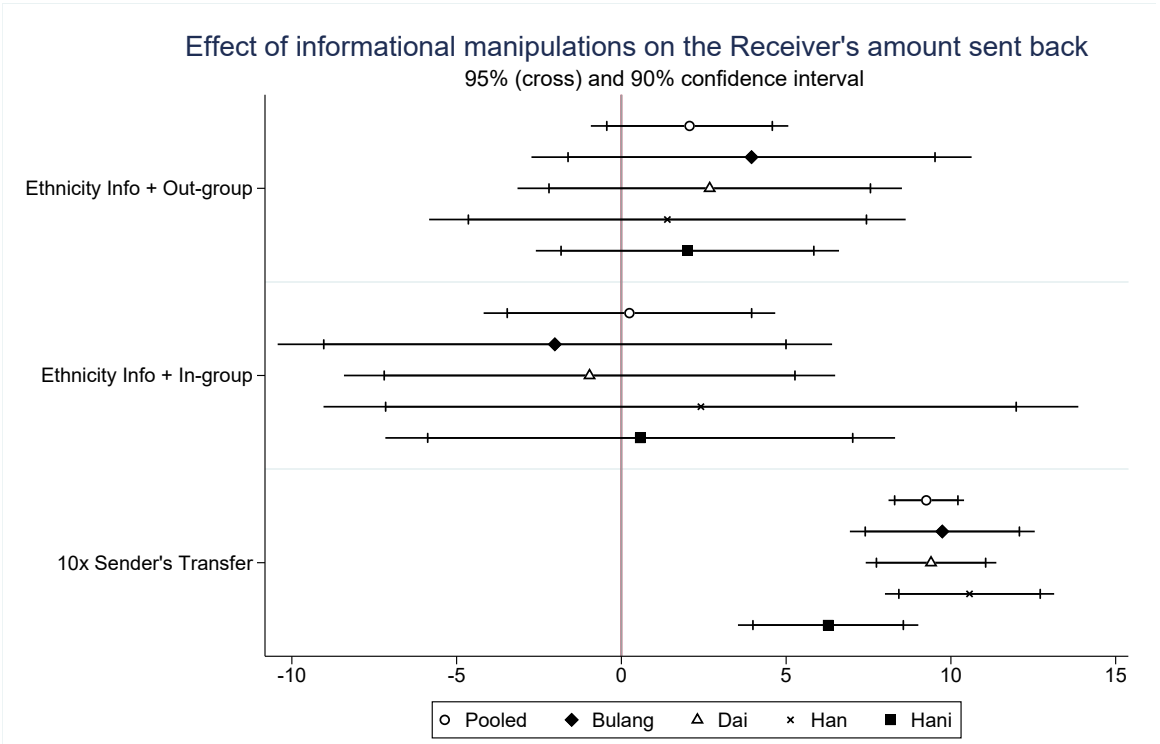
Overall, the lack of statistical significance of the treatment variables and the high significance of the sender's transfer suggest that second movers give more weight to the game-specific information, namely the received transfer, than to the information about their partners' ethnicity. Hence, our insights regarding the relationship between trustworthiness and in-group/out-group ethnicity are limited and must be interpreted with caution.

1.5.3 Religion as an alternative cue for senders and receivers

Although our matching within the trust game was based on ethnicity, it was highly correlated with religious affiliation. One would expect this relationship given the description in Section 1.4 regarding the tight connection between ethnicity and religion in Banna. The main implication of this feature of the sampling is that, since to any player we disclose information either about ethnicity or about religion but not about both simultaneously, we are not able to test whether identity in this context is driven more strongly by religious identification than by ethnic identification. Either may be functioning as a signal of the other.

[13] This feature of our design makes it less likely that multiple observations from a subject are independent from each other, because the history of the game may have an effect. Nonetheless, the random payment of only one of the five rounds decreases the interdependency across the multiple observations per player.

Figure 1.3: **OLS coefficients for the treatment variables on the amount sent back by the receiver.** The reported coefficients, for the effect of disclosing in-group and out-group ethnicity and the effect of the sender's transfer, correspond to five different estimations: a pooled regression with subjects of different ethnicities, plus one regression for each ethnicity. For each point estimate we show the 95% (vertical line) and 90% (end of line) confidence intervals. The units are the points sent back.



Note: The dependent variable is the amount sent back by a receiver in a round × session. The analysis is based on the participants that at least played once with a different ethnicity in all the five rounds, i.e. 275 participants. We further exclude the rounds where the sender's transfer was null. Ethnicity, religion and session FE are controlled. Geographical closeness and individual characteristics including age, gender, education, marital status, self-perceived relative wealth, and a dummy of being farmer are controlled. The results are in Table A.6.

As a robustness test we therefore present the results of the trust game, for the sender and the receiver, when religious affiliation is disclosed.

Figure 1.4 plots the coefficients of a regression analysis similar to the one for ethnicity, showing senders in the upper panel and receivers in the lower panel). In the upper panel, the results for the pooled sample of senders reveal a similar effect of in-group favoritism (+3.2 points, for ethnicity it was +3.3 points) when the disclosed receiver's religious affiliation is the same. Nonetheless, religious in-group favoritism is statistically significant only for the Dai (+8.0 points). Since the Dai participants correspond to 47% of our sample, it is plausible that the effect in the pooled regression, which is just marginally statistically significant, is mostly driven by the

Figure 1.4: **OLS coefficients for the religion-related treatment variables** on the transfer from the sender (top) and the amount sent back by the receiver (bottom). The reported coefficients, for the effect of disclosing in-group and out-group ethnicity and the effect of the sender's transfer, correspond to five different estimations: a pooled regression with subjects of different ethnicities, plus one regression for each ethnicity. For each point estimate we show the 95% (vertical line) and 90% (end of line) confidence intervals. The units are the points sent by senders and those sent back by receivers.

Note: The dependent variable is the amount sent by a sender (or sent back by a receiver) in a round $\times$ session. The analysis is based on the participants that at least played once with a different ethnicity in all the five rounds, i.e. 241 senders and 275 receivers. For the regressions on receivers, we further exclude the rounds where the sender's transfer was null. Ethnicity, religion and session FE, geographical closeness and individual characteristics are controlled. The results are in Table A.5 and Table A.6.

Dai participants. The lower panel reveals that, for the pooled sample, the effects of disclosing religious affiliation are not statistically significant in predicting transfers to the in-group or out-group.

We thus conclude that disclosing religious affiliation has similar effects to the disclosure of ethnicity. Presumably this is because both are highly correlated in the context of our sample, and disclosing one dimension of identity conveys a strong signal about the other dimension.

1.6 Results: Public goods games

1.6.1 Contributions to the public fund

Table 1.4 provides details of contributions and punishment levels by group type, distinguishing not just homogeneous and mixed groups but also the balanced from the unbalanced mixed groups. We also distinguish behavior in the first round from that in subsequent rounds where it is subject to the influence of prior punishment. Subjects contribute on average 63% of their endowment.

It can be seen from the table that the behavior of unbalanced mixed groups is very different from that of the other two types, in the sense that contribution levels are lower initially, do not rise after the first round (unlike in the other groups) and punishment levels are lower. Of course, group level variables are equilibrium outcomes of the interactions of individual decisions, and it is important to see how these are affected by many variables, including group composition and the behavior of fellow group members.

Table 1.5 reports OLS regressions that examine whether individual contribution behaviors

Table 1.4: Means and standard deviations of amounts contributed and punishments inflicted in the public goods game - by round and group type.

	Contribution		Punishment inflicted	
	Round 1	Rounds 1-5	Round 1	Rounds 1-5
Homogeneous Groups (N=300)	5.72±2.98	6.42±3.08	0.65±0.98	0.60±0.96
Balanced Mixed Groups (2+2) (N=236)	5.66±3.02	6.36±3.15	0.58±0.89	0.60±0.91
Unbalanced Mixed Groups (3+1) (N=40)	4.55±2.47	4.73±3.02	0.42±0.71	0.56±0.85

Table 1.5: OLS regressions explaining contribution levels for all the rounds and the first round in the public goods game

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Contribution - All rounds			Contribution - First round		
One non co-ethnic	-1.531***	-1.055**	-0.903*	-1.172**	-0.719	-0.526
	(0.503)	(0.530)	(0.518)	(0.515)	(0.586)	(0.581)
Two non co-ethnics	-0.563**	-0.166	0.0838	-0.297	0.0548	0.372
	(0.247)	(0.332)	(0.354)	(0.250)	(0.407)	(0.469)
Three non co-ethnics	-0.434	-0.0465	0.372	0.0932	0.434	0.923
	(0.894)	(0.851)	(0.847)	(0.899)	(0.851)	(0.902)
Sender		0.224	0.323		0.0141	0.144
		(0.427)	(0.437)		(0.545)	(0.560)
Amount sent x Sender		0.0459***	0.0443***		0.0580***	0.0552***
		(0.0108)	(0.0109)		(0.0142)	(0.0145)
Share sent back x Receiver		1.251***	1.256***		1.413***	1.359***
		(0.390)	(0.382)		(0.479)	(0.467)
Constant	7.275***	6.036***	5.931***	5.720***	4.428***	4.038***
	(0.710)	(0.759)	(0.878)	(0.771)	(0.847)	(1.082)
Observations	2,445	2,445	2,445	489	489	489
R-squared	0.225	0.255	0.269	0.168	0.217	0.242
Individual controls			Yes			Yes

Note:The dependent variable is the points contributed by each player in each round. The analysis is based on 489 out of 576 participants, after excluding problematic participants. Standard errors clustered at the group level, shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Session, round, and ethnicity fixed effects are controlled. The individual controls include age, gender, education, marital status, self-perceived relative wealth, a dummy of being farmer, and geographical closeness.

vary by group composition.[14] We look at the levels of contributions of all rounds (columns 1-3) and the levels of contribution for the first round (columns 4-6). To disentangle the effect of being in a mixed group, we test the "intensity" of mixed groups by adding a variable that captures the number of non-co-ethnics in the group. This is useful to fully examine the heterogeneity in contribution behaviors, by group composition. The baseline is being in the homogeneous groups (zero non co-ethnics). We control the effect of being a sender and average earnings in the trust game previously played (Table A.4).

[14] These results are similar when conducting Tobit regressions that take into account the censoring problems due to the proportion of participants selecting full and null contributions.

We find that the coefficients for the number of non co-ethnics increase monotonically. That is, the more non co-ethnics in the group, the less negative is the difference in contributions with respect to the homogeneous group. One interpretation is that the presence of more non co-ethnics is associated with more fear of being punished for a low contribution. With only one non-coethnic present contributions fall substantially (by about 25%).

Controlling for subjects' behavior in the trust game reduces the coefficient on one non-coethnic by about a third but it remains large and significant at the 5% level. Both the amount sent by senders and the proportion returned by receivers are strongly significant predictors of contributions in the public goods game, as woudl be expected if they capture trustingness and trustworthiness respectively.

1.6.2 Punishment

We now investigate the determinants of punishment, including the presence or absence of shared ethnic identity between fellow group members. Table 1.6 shows the results of OLS estimation of the probability that an individual i punishes an individual j, as a function of the difference in contribution levels between i and j, plus dummy variables indicating whether the two individuals are co-ethnics in a mixed group, or from different ethnicities (the omitted category is being in an homogeneous group). We include round, ethnic and session fixed effects. The latter are particularly important to control for any differences in the propensity to punish that might occur between sessions due to possible variations in the presentation by the experimenters, which are impossible to exclude completely in a field setting although experimenter training attempts to minimize them.[15] We run separate estimations for the cases where i contributes more than j (columns 1-4) and for the cases where i contributes less than j (columns 5-8). These two cases will reflect quite different motivations - the former involving punishment of free-riders and the latter involving punishment of high contributors, sometimes known as "anti-social punishment" (Herrmann, Thöni and Gächter, 2008). We find no evidence of systematic anti-social punishment.

Our most striking results come from patterns of punishment of free-riders. Here four findings findings stand out. First, subjects' behavior in the trust game is of negligible importance. This makes sense as punishment is about responding to recent behavior of the partner and should not be expected to reflect either trustingness or trustworthiness.

[15] The inclusion of fixed effects explains why we use OLS estimation rather than probit or logit, which would lead to biased parameter estimates due to the incidental parameters problem. Moreover, we added interaction terms that make the interpretation of non-linear models more convoluted (Ai and Norton, 2003).

Table 1.6: Linear probability model for the likelihood that *i* punishes *j*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Positive Contribution Gap				Negative Contribution Gap			
Own contribution	-0.016***	-0.017***	-0.016***	-0.017***	-0.005	-0.005	-0.005	-0.005
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Mixed group	0.004	0.020	0.016	0.021	-0.009	-0.020	-0.031	-0.029
	(0.027)	(0.042)	(0.045)	(0.045)	(0.025)	(0.036)	(0.041)	(0.038)
Mixed own ethnic.	-0.055***	-0.055***	-0.051**	-0.042	-0.007	-0.007		-0.009
	(0.021)	(0.021)	(0.025)	(0.026)	(0.020)	(0.021)		(0.023)
Contri. Gap i over j	0.030***	0.030***	0.030***	0.031***	0.004	0.004	0.004	0.007
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)
Mixed group x Gap				-0.001				-0.004
				(0.009)				(0.007)
Mixed own ethnic. x Gap				-0.006				-0.001
				(0.008)				(0.007)
Sender		-0.015	-0.027	-0.015		-0.049	-0.066	-0.048
		(0.057)	(0.056)	(0.057)		(0.049)	(0.049)	(0.049)
Amount sent x Sender		0.001	0.001	0.001		0.001	0.002	0.001
		(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
Share sent back x Receiver		-0.027	-0.029	-0.027		-0.015	-0.026	-0.014
		(0.039)	(0.038)	(0.039)		(0.044)	(0.044)	(0.044)
Constant	0.374***	0.372***	0.521***	0.368***	0.265***	0.287***	0.470***	0.293***
	(0.088)	(0.101)	(0.118)	(0.100)	(0.079)	(0.094)	(0.123)	(0.095)
Individual controls			Yes				Yes	
Observations	4,504	4,504	4,504	4,504	4,524	4,524	4,524	4,524
Wald chi2	434.84	495.69	577.57	517.17	275.44	363.02	461.78	383.30

Note:The dependent variable is whether a player punishes another player in a round×session. The analysis is based on 489 out of 576 participants, after excluding problematic participants. Positive contribution gap refers to the case where player *j* contributes no less than player *i*, vice versa. Standard errors are clustered at the group level, shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The round, ethnicity and session fixed effects and individual random effects are controlled. The individual controls include age, gender, education, marital status, self-perceived relative wealth, a dummy of being farmer, and geographical closeness.

Secondly, controlling for the gap between the subject and the partner, subjects who have contributed more are less likely to punish. This suggests a correlation between generous traits and tolerance of the lower contributions of others.

Thirdly, the greater the contribution gap between the subject's contribution and that of the partner, the greater is the likelihood of punishment, a result that has also been found in the literature (see Dreber et al. (2008)).

Most strikingly, behavior in mixed groups is quite different from that in homogeneous groups - within mixed groups subjects are more than 5 percentage points less likely to punish in-group members than out-group members, a difference that is significant at 1% without controls and at 5% with controls. This is partly because they punish out-group members slightly more than

subjects punish co-ethnics in homogeneous groups (by around 2 percentage point in columns 3 and 4, though this is not statistically significant). To a greater extent it is because they punish their co-ethnics less than do subjects in homogeneous groups. It is not because they respond with greater sensitivity to the contribution gap, as can be seen in column 4.

1.6.3 Robustness checks

Gender differences

In a similar public goods game with punishment involving a minority (Spanish *Gitanos*), Espín et al. (2019) find that women contribute less (resp. more) than men in homogeneous (resp. mixed) groups. Moreover, *Gitano* women did not punish in any group configuration while *Gitano* men only punished in mixed groups. By contrast, non-*Gitano* women punished more in homogeneous groups. Following Espín et al.'s argument that these results are linked to culture-specific differential gender roles in norm enforcement, we explore whether a similar pattern emerges in the context of our study.

Tables A.7 and A.8 in the Appendix show gender effects on sender and receiver transfers in the Trust game. In keeping with the existing literature we find that women send less and return less, but there is no evidence of a gender difference in the effect of ethnicity or religion (an apparent effect in column 1 of Table A.7 disappears once session fixed effects are included).

We have similar findings in the public goods games, as can be see in Tables A.9 and A.10. There are no gender effects at all on contributions, and while there is a lower probability of punishment on average by female subjects. This reduced probability disappears when we add gender interactions with ethnicity.

Balanced mixed groups

A potential concern with having balanced and unbalanced mixed groups is that in those groups with a single player from one ethnicity the dynamics of punishment might be different (for instance, this participant might be more afraid of retaliations and punish less). We thus conduct again the regressions from Table 1.6, excluding the unbalanced mixed groups. The results are qualitatively identical (see Table A.11 in the Appendix), although the difference in probability of punishing own and other ethnics in mixed groups is 4.8 percentage points instead of 5.5 points, a difference that is significant at the 5% level. We thus argue that the results were

not driven by the presence of unbalanced mixed groups.

1.7 Discussion

An important literature in economics and political science has identified ethnic diversity as a predictor of low cooperation and public good provision in many different social contexts (see Alesina, Baqir and Easterly (1999)). Habyarimana et al. (2007) find evidence in favor of two mechanisms that may explain this phenomenon: one is differences in strategy selection by individuals, while the other consists of differences in the sanctioning technology to which individuals have access, based on their differential closeness to others within the social network.

The experiments we conducted allow us to explore the preference and strategy selection mechanisms directly, by giving all subjects access to the same sanctioning technology regards of network closeness. We analyze whether individuals behave differently according to their counterpart's ethnicity. We find an in-group favoritism from the senders in the trust game towards co-ethnics: transfers are about 16% larger compared to the baseline situation without any type of information about the receiver. On the other hand, the transferred amounts do not indicate any hostility towards out-group members with respect to the baseline situation in which individuals know nothing about their interaction partner.

Most importantly, we interpret this in-group favoritism as evidence of strategy selection. Whereas the sender transferred more points in the presence of a cue of shared ethnicity with the receiver, this information was not predictive of the transfer made by the receiver. If the larger transfer were directly associated to preference differences, one would expect that the receiver also repay more to co-ethnics. Instead, a less noisy signal (i.e., the amount transferred by the sender) becomes the main predictor of receiver's behavior.

It is important to mention that the sender's in-group favoritism is subject to non-negligible variation across ethnic groups. Gupta et al. (2018) finds that senders from the minority exhibit a greater in-group bias. In our case, this bias is greater for one of the minorities (Bulang), followed by the local majority (Dai) and then by the country's majority (Han). So far, our findings are similar to Gupta et al.'s results. However, for the other minority in our sample (Hani), we find slightly smaller transfers towards co-ethnics than in absence of information (though this difference is not statistically significant). This may reflect the fact that Hani senders returned systematically fewer points than the other ethnic groups to their senders for any given amount

received. We thus replicate Gupta et al.'s findings with subjects from ethnic groups that did not behave differently in the baseline, while leaving open the possibility that Hani players behave less generously towards their own in-group because of knowledge about the lower general reciprocal tendencies of their own in-group.

The symmetric punishment opportunities in our public goods game allow us to abstract from real-world differences in punishment opportunities, and to study other mechanisms present during the punishment stage of the game. In Habyarimana et al.'s argument, the greater closeness in the social network for co-ethnics than for non co-ethnics creates more chances to coordinate and to sustain credible threats in homogeneous groups. Miguel and Gugerty (2005) make a similar point, arguing that the lack of access to social sanctions in mixed settings contributes to the negative association between ethnic diversity and public goods provision.

In our experiment, in contrast, the access to a punishment technology is the same for co-ethnics and non co-ethnics. We find that the likelihood of punishing a group member changes in mixed groups, with in particular a lower probability of punishing in-group members. This may be related to the behavior reported in Eriksson, Mao and Villeval (2016). In an intergroup context subjects are willing to incur in a cost to avoid the public exposure of the worst performer in their group. While not the same behavior as that observed in our setting (notably because punishment does not become public information), it indicates that preserving in-group solidarity may be an important consideration, at least in ethnically mixed contexts among our populations.

Such differences in punishment behavior are likely to have a greater effect on contribution levels in groups in which one ethnic group is in a majority. In such groups there are three majority members and only one minority member. The majority members can count on a lower punishment risk from two of the other three players.

Figure 1.5 let us explore this behavior. The left panel shows that average contributions in the homogeneous and balanced mixed groups are initially higher than in unbalanced mixed groups and that the difference grows over time, whereas average contributions for the latter group composition remains roughly constant over time. It is worth noting that our public goods games lasted for only five periods; over a longer period of interaction the differences, if extrapolated, might well have become substantially greater.

The right panel in Figure 1.5 shows that punishment levels early in the game are substantially lower in mixed heterogeneous groups (3+1) than in the other two groups, only catching up in

Figure 1.5: Contribution levels and allocated disapproval cards by group composition and round

later rounds. This catching up is driven by the substantial increase of punishment from the single member of an ethnicity playing with three group-members from the other ethnicity in the session. Recall from Table 1.5 that participants in mixed groups were more likely to reduce their contribution in presence of a single non co-ethnic. Thus, the increase in punishment is the response of the single member of an ethnicity within a group. Presumably, once she updates the expectations of a low likelihood of anti-social punishment. Nonetheless, contribution rates remain stable because the other group members do not engage in costly punishment.

Table 1.7 verifies that these differences in contribution levels lead, as we might expect, to lower final earnings for the participants in mixed groups, though the differences are not statistically significant without the inclusion of additional controls. When we separate asymmetric (3+1) from symmetric (2+2) mixed groups the difference in earnings from the homogeneous groups is three times as great for the asymmetric as for the symmetric groups. The effect once again depends on the inclusion of likely endogenous controls (notably the amount of punishment inflicted in the group) so the conclusions concerning earnings must necessarily be tentative. In any case the outcomes at group level are the result of interactions between individuals and so can be expected to be less well identified than individual behavioral responses to treatments. Nevertheless, it seems plausible that the favoritism that individuals in our study show towards co-ethnics in mixed groups may lead to a lower level of group discipline and therefore be harmful for those it purports to help.

Table 1.7: OLS regression for group's total earnings in the public goods game.

VARIABLES	(1)	(2)	(3)	(4)
Mixed group	-10.31	-10.38*		
	(8.225)	(4.769)		
Mixed group: 2+2			-12.43	-7.740
			(8.796)	(5.931)
Mixed group: 3+1			1.311	-24.87**
			(29.96)	(6.338)
Total Punishment Cards Allocated		-7.390***		-7.455***
		(0.385)		(0.372)
Constant	394.2***	400.1***	395.5***	398.6***
	(4.935)	(2.885)	(5.277)	(3.648)
Observations	144	144	144	144
R-squared	0.527	0.920	0.528	0.921

Note:The dependent variable is the total earnings of a group in the five rounds. There are 144 groups, formed by 576 participants. Session fixed effects included in the regressions. Standard errors clustered at the location level are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

1.8 Conclusion

Yunnan Province in China is a context in which relations between ethnic groups are largely harmonious in spite of substantial social, economic, linguistic and cultural differences between groups. That our study has nevertheless found tendencies to favoritism towards in-group members is striking. This favoritism includes notably a diminished willingness to discipline free-riders in mixed public goods games, with potentially adverse effects on cooperation in such games.

It remains to be seen how general are such findings. One possible application is to corruption, which in many countries includes corrupt behavior not just by those in power, but also (and particularly) by their relatives, friends and co-ethnics. It is often when the President's *relatives*, rather than just the President, help themselves to the spoils of office that the outrage provoked by corruption is strongest. If part of the reason is that those in power are reluctant to discipline corrupt behavior by other members of their in-group, the phenomenon we have uncovered may have a much wider application than just to the provision of public goods.

Another possible application may be to understanding the physical insecurity felt by minority individuals in city neighborhoods dominated by another ethnic group. It may be not so much that they fear greater intrinsic hostility by the majority, rather as a reduced willingness on the part of majority individuals to punish opportunistic violence by their co-ethnics. This possibility remains an interesting subject for future research.

Appendix 1.A Additional Tables

Table A.1: Balance check on observable characteristics in the treatment assignment for the public goods game.

	Group composition		Difference	p-value
	Homogeneous	*Mixed*		
Demographics				
Age	32.576	33.065	-0.489	0.635
Gender (1=female)	0.490	0.491	-0.001	0.981
Farmer	0.529	0.513	0.016	0.720
Education (1=secondary degree)	0.206	0.220	-0.014	0.714
Religious affiliation				
Atheist	0.191	0.250	-0.059	0.113
Buddhist	0.545	0.522	0.023	0.609
Christian	0.222	0.190	0.032	0.382
Original religions	0.043	0.039	0.004	0.824
Ethnicity				
Bulang	0.136	0.181	-0.045	0.175
Dai	0.553	0.422	0.130***	0.004
Han	0.183	0.237	-0.054	0.141
Hani	0.128	0.159	-0.031	0.328

The table is based on 489 out of 576 participants, after excluding problematic participants. explained in Table A.3. *** p<0.01, ** p<0.05, * p<0.1

Table A.2: Distribution of religion by location

Location	Atheist	Buddhist	Christian	Original
Dadugang	35	42	11	0
Daluo	31	150	0	23
Gasa	2	31	27	0
Jinghong	21	21	106	0
Menghun	20	44	0	12

Table A.3: **Composition of subjects by session** The table summarizes the composition of players by ethnicity, religion (B:Buddhist, A:Atheist, O:Original and C:Christian), and village group (VG). Due to privacy concern, we replace village names by numbers.

Day	Session	City/Town	Composition				
			ethnicity1	religion (by VG)	ethnicity2	religion by VG	Problematic
1	1	Daluo	10 Dai	10B(VG1)	10Bulang	10B(VG2)	
1	2	Daluo	10 Dai	10B(VG1)	6Bulang	6B(VG2)	
2	3	Daluo	6 Bulang	1B(VG4), 4B+1O(VG3)	6Hani	3A+3O(VG3)	
2	4	Daluo	10 Bulang	3B(VG4), 7B(VG3)	10 Hani	2O+3B*+3A(VG3) 1O+1A (other)	
2	5	Daluo	11 Bulang	8B(VG3), 3B(VG4)	9Hani	1B+1O+7A(VG3)	1 Hani
3	6	Daluo	10 Bulang	9B+1O(VG6)	10 Dai	10B(VG5)	1 Bulang
3	7	Daluo	10 Bulang	5B+1O(VG6), 4B(VG4)	10 Dai	10B(VG5)	
4	8	Daluo	6 Bulang	5B(VG6), 1B(other)	10 Dai	10B(VG5)	
4	9	Daluo	11 Bulang	11B(VG4)	9 Hani	5O(VG3), 4O(VG7)	
5	10	Daluo	10 Bulang	4B+1O(VG2), 4B(VG8), 1B(other)	10Hani	2O+8A(VG9)	
5	11	Daluo	10 Dai	10B(VG10)	10 Hani	1O+9A(VG9)	
6	12	Menghun	10 Dai	10B (5 VGs)	10Hani	2B+2O+6A(VG12)	
6	13	Menghun	10 Dai	3B(other), 6B+1O(VG11)	10 Hani	2A+8O(VG12)	
6	14	Menghun	9 Hani	8A+1O(VG14)	11Dai	10B+1A(VG13)	
6	15	Menghun	5 Hani	3A+2B(VG14)	11Dai	11B(VG13)	
7	16	Gasa	20 Dai	10B(VG15), 10C(VG16)			1 Dai
8	17	Gasa	10 Han	7C+2A(VG17), 1C(VG18)	10 Dai	10B(VG15)	2 Han
8	18	Gasa	9 Han	9C(VG18)	11 Dai	10B(VG15)	3 Han
9	19	Jinghong	10 Dai	10C(Church1)	6 Han	6C(Church1)	2 Han
9	20	Jinghong	8 Dai	8C(Church1)	12 Han	12C(Church1)	
10	21	Jinghong	12 Dai	10C(Church1), 1B+1A(other)	8Han	7C(Church1), 1A(other)	1 Dai
10	22	Jinghong	10 Han	1C(Church1), 9A(other)	10 Dai	1C(Church1), 9B(other)	
10	23	Jinghong	9 Han	2C(Church1), 2B+5A(other)	7 Dai	7B(other)	
11	24	Mengman	13 Dai	2C+11B(VG19)	7 Han	5C+2A(VG20)	1 Han
11	25	Mengman	16 Dai	5A+11B(VG19)	4 Han	1A in(VG21), 1B(VG22) 2C(VG19)	2 Dai, 1 Han
11	26	Mengman	9 Dai	1C+6B(VG19), 2B (other)	7 Han	5A+2B(VG19)	3 Han
11	27	Mengman	8 Dai	4B+4A(VG19)	8 Han	1C+7A(VG19)	
11	28	Mengman	7 Dai	2A+5B(VG19)	9 Han	4A(VG23), 2A(VG21), 2A+1B(VG19)	
12	29	Jinghong	11 Han	10C+1A(Church2)	9 Dai	8C+1A(Church2)	3 Dai, 1 Han
12	30	Jinghong	10 Han	10C(Church2)	10 Dai	10C(Church2)	5 Han
12	31	Jinghong	8 Han	5C(church2), 1B+2A(other)	8 Dai	7C+1A(Church2)	

Notes: The composition is based on subjects' reported village, experiment records, and government detailed records of ethnicity composition of each village group. The "problematic participants" refer to the participants in three sessions (session 9 and session 20 with large-scale misreporting of ethnicity and session 11 where participants talked aloud to coordinate) and 27 participants with mismatched ethnicity (the ethnicity reported at the beginning of the game does not match that in the questionnaire).

Table A.4: Treatment assignment for the public goods game with respect to the role in the trust game

	Homogeneous group	Mixed group	Difference	p-value
Sender	0.837	0.121	-0.716***	0.000

The table is based on 489 out of 576 participants, after excluding problematic participants. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table A.5: OLS Regression results for the Sender's transfer

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Pooled		Bulang		Dai		Han		Hani	
Ethnicity Info	0.158	0.238	-3.255	-2.403	-1.524	-1.109	2.548	2.193	2.668	2.707
	(0.944)	(0.937)	(2.442)	(2.383)	(1.710)	(1.660)	(1.795)	(1.743)	(1.983)	(2.090)
Same ethnicity	0.297	0.114	-0.808	-1.160	-2.915*	-3.510**	2.260	1.983	4.116	4.477**
	(1.074)	(0.959)	(2.521)	(2.208)	(1.739)	(1.599)	(1.894)	(1.592)	(2.506)	(2.188)
Ethnicity Info × Same ethnicity	3.404**	3.299**	10.407**	8.507**	7.211***	6.150***	0.206	0.313	-4.252	-4.360
	(1.485)	(1.423)	(4.197)	(4.128)	(2.419)	(2.110)	(2.605)	(2.397)	(2.959)	(3.039)
Religious Info	0.700	0.767	-0.074	0.122	-2.478	-2.402	3.015	2.087	2.226	2.164
	(1.097)	(1.091)	(2.895)	(3.025)	(2.345)	(2.273)	(2.363)	(2.289)	(1.702)	(1.767)
Same religion	-0.280	-0.171	-4.227	-2.620	-1.312	1.661	-0.705	-1.648	2.351	2.881
	(1.224)	(1.106)	(3.286)	(3.168)	(2.374)	(1.921)	(1.943)	(1.910)	(2.017)	(2.009)
Religious Info × Same religion	3.260**	3.212**	5.295	4.924	8.173***	7.967***	-0.474	0.514	-3.505	-3.299
	(1.439)	(1.380)	(3.801)	(3.903)	(2.725)	(2.586)	(2.642)	(2.619)	(2.911)	(2.862)
Closeness	-1.863	-1.336	2.856	6.486*	-4.984	-4.256*	2.868	-1.026	-2.305	-1.577
	(1.696)	(1.606)	(3.568)	(3.647)	(3.158)	(2.421)	(3.040)	(2.742)	(4.351)	(3.942)
Dai	0.500	1.073								
	(1.968)	(2.545)								
Han	0.865	3.604								
	(2.944)	(3.573)								
Hani	-4.001	-5.841**								
	(2.675)	(2.850)								
Constant	26.342***	25.565***	16.816***	12.724**	23.342**	37.712***	38.966***	41.338***	31.035***	25.033**
	(4.775)	(5.020)	(5.715)	(5.513)	(9.308)	(10.744)	(9.027)	(10.735)	(9.664)	(10.025)
Observations	1205	1205	225	225	425	425	320	320	235	235
R^2	0.105	0.249	0.184	0.294	0.083	0.419	0.172	0.339	0.272	0.350
Session FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Religion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable is the amount sent by a sender in a round × session. The analysis is based on the participants that at least played once with a different ethnicity in all the five rounds, i.e. 241 senders. Standard errors clustered at the individual level are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The geographical closeness and individual characteristics including age, gender, education, marital status, self-perceived relative wealth, and a dummy of being farmer are controlled.

Table A.6: OLS Regression results for the Receiver's transfer

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Pooled		Bulang		Dai		Han		Hani	
Ethnicity Info	2.231	2.069	4.616	3.950	4.095	2.681	1.403	1.397	1.855	2.005
	(1.477)	(1.521)	(3.204)	(3.314)	(2.718)	(2.932)	(3.538)	(3.618)	(2.301)	(2.284)
Same ethnicity	1.540	0.422	-0.388	-0.154	-2.058	-3.427	9.946*	9.000*	0.015	-0.724
	(1.947)	(1.985)	(3.673)	(3.549)	(2.900)	(2.991)	(5.121)	(5.071)	(2.268)	(2.740)
Ethnicity Info × Same ethnicity	-0.355	0.245	-3.093	-2.018	-4.031	-0.965	1.574	2.414	0.817	0.572
	(2.200)	(2.246)	(4.098)	(4.174)	(3.493)	(3.747)	(5.769)	(5.731)	(3.933)	(3.840)
Religious Info	3.761**	3.573*	8.977**	8.426*	6.419	4.924	4.441	4.444	3.156	3.328
	(1.822)	(1.956)	(4.110)	(4.264)	(4.519)	(5.028)	(3.494)	(3.723)	(2.899)	(2.942)
Same religion	-0.582	-1.192	1.780	0.354	-1.671	-2.607	-2.966	-4.009	2.911	2.061
	(1.761)	(1.915)	(5.295)	(4.398)	(3.532)	(3.685)	(3.713)	(4.170)	(2.030)	(2.130)
Religious Info × Same religion	0.520	1.206	-7.519	-6.860	-3.604	-0.899	5.056	5.915	-2.484	-2.674
	(2.287)	(2.409)	(4.748)	(4.996)	(4.400)	(4.864)	(5.859)	(6.248)	(4.768)	(4.732)
10x Sender's Transfer	9.864***	9.253***	9.571***	9.740***	10.491***	9.397***	10.765***	10.566***	5.754***	6.275***
	(0.635)	(0.582)	(1.512)	(1.392)	(1.081)	(0.996)	(1.173)	(1.285)	(1.144)	(1.359)
Dai	0.779	-3.167								
	(1.950)	(2.008)								
Han	1.094	-0.648								
	(2.594)	(2.626)								
Hani	-2.107	-3.134								
	(2.427)	(2.176)								
Closeness	3.208*	3.518	-2.735	-6.267*	9.541***	6.892	6.677	8.282	1.498	3.080
	(1.779)	(2.191)	(3.444)	(3.631)	(3.218)	(4.473)	(4.657)	(5.363)	(2.444)	(4.734)
Constant	2.903	6.727	6.258	9.563	0.024	1.295	-2.553	-1.070	-1.155	1.196
	(4.502)	(4.092)	(7.222)	(6.277)	(7.731)	(9.064)	(11.036)	(9.980)	(4.824)	(6.457)
Observations	1147	1147	211	211	411	411	308	308	217	217
R^2	0.387	0.438	0.417	0.442	0.378	0.453	0.458	0.491	0.325	0.355
Session FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Religion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable is the amount sent back by a receiver in a round × session. The analysis is based on the participants that at least played once with a different ethnicity in all the five rounds, i.e. 275 receivers. We further exclude the rounds where the receiver receives zero. Standard errors clustered at the individual level are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The geographical closeness and individual characteristics including age, gender, education, marital status, self-perceived relative wealth, and a dummy of being farmer are controlled.

Table A.7: OLS Regression results for the Sender's transfer with gender interactions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Pooled		Bulang		Dai		Han		Hani	
Female	-4.976***	-3.415**	-8.575**	-6.729*	0.084	3.328	-5.628*	-6.986***	-9.391***	-7.375*
	(1.539)	(1.494)	(3.406)	(3.568)	(2.839)	(2.466)	(2.843)	(2.504)	(2.965)	(3.677)
Ethnicity Info × Same ethnicity	1.403	1.962	3.492	2.096	3.475	3.101	1.788	2.739	-1.799	-1.739
	(1.616)	(1.487)	(4.527)	(4.525)	(3.066)	(2.485)	(2.598)	(2.410)	(2.328)	(2.475)
Ethnicity Info × Same ethnicity × Female	3.509*	2.303	3.509	4.471	0.701	0.907	1.573	-0.601	4.233	3.184
	(1.828)	(1.740)	(5.486)	(5.629)	(2.976)	(2.589)	(3.350)	(3.115)	(3.094)	(3.156)
Religious Info × Same religion	2.664	3.694**	2.512	3.252	4.282	5.990**	4.027	4.194	0.686	0.792
	(1.808)	(1.620)	(4.144)	(4.190)	(3.153)	(2.606)	(2.775)	(2.685)	(3.739)	(3.670)
Religious Info × Same religion × Female	1.685	0.012	3.289	2.218	0.911	-0.684	-3.692	-4.104	-0.145	-0.596
	(2.095)	(1.901)	(4.919)	(4.853)	(3.399)	(2.804)	(3.478)	(3.191)	(5.252)	(5.327)
Dai	0.555	1.116								
	(1.964)	(2.551)								
Han	0.994	3.642								
	(2.914)	(3.578)								
Hani	-3.939	-5.839**								
	(2.651)	(2.846)								
Constant	27.075***	26.098***	14.459**	10.773**	20.892**	36.018***	41.221***	42.860***	33.302***	26.783**
	(4.818)	(5.065)	(5.909)	(5.239)	(9.186)	(10.823)	(8.965)	(10.416)	(9.706)	(10.365)
Observations	1205	1205	225	225	425	425	320	320	235	235
R^2	0.107	0.249	0.170	0.290	0.076	0.410	0.169	0.337	0.260	0.334
Session FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Religion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable is the amount sent by a sender in a round × session. The analysis is based on the participants that at least played once with a different ethnicity in all the five rounds, i.e. 241 senders. Standard errors clustered at the individual level are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The geographical closeness and individual characteristics including age, gender, education, marital status, self-perceived relative wealth, and a dummy of being farmer are controlled.

Table A.8: OLS Regression results for the Receiver's transfer with gender interactions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Pooled		Bulang		Dai		Han		Hani	
female	-3.056*	-3.310**	-6.333*	-6.094	-0.326	3.905	-4.101	-3.104	-2.196	-4.028*
	(1.735)	(1.434)	(3.576)	(4.222)	(3.848)	(2.820)	(3.243)	(2.778)	(1.715)	(2.111)
Ethnicity Info × Same ethnicity	1.418	1.378	-6.897*	-5.949	-1.879	1.374	7.322	7.092	3.813	2.774
	(2.626)	(2.678)	(3.588)	(3.674)	(4.245)	(4.627)	(7.595)	(7.811)	(4.869)	(4.615)
Ethnicity Info × Same ethnicity × female	-0.320	-0.794	9.305*	8.457	-3.586	-5.782	1.714	1.330	-4.058	-3.323
	(3.173)	(3.196)	(5.050)	(5.043)	(5.308)	(5.579)	(8.469)	(8.644)	(5.423)	(5.287)
Religious Info × Same religion	3.834	4.382	-5.287	-5.180	2.076	6.015	13.119**	13.596**	4.150	2.572
	(2.749)	(2.685)	(5.490)	(5.623)	(4.519)	(4.417)	(5.742)	(5.979)	(6.150)	(6.142)
Religious Info × Same religion × female	-1.407	-2.109	6.783	6.858	-4.865	-8.297	-3.938	-4.509	-6.563	-5.102
	(3.299)	(3.217)	(6.587)	(6.626)	(5.313)	(5.246)	(7.070)	(7.285)	(7.120)	(7.249)
10x Sender's Transfer	9.896***	9.288***	9.527***	9.750***	10.544***	9.461***	10.963***	10.717***	5.888***	6.381***
	(0.639)	(0.584)	(1.543)	(1.387)	(1.111)	(1.008)	(1.203)	(1.325)	(1.173)	(1.340)
Dai	0.907	-3.089								
	(1.955)	(2.015)								
Han	1.327	-0.625								
	(2.633)	(2.632)								
Hani	-1.782	-3.064								
	(2.450)	(2.161)								
Constant	4.528	8.225*	12.925*	15.318**	0.482	-0.124	0.187	1.441	-0.278	2.402
	(4.592)	(4.197)	(7.550)	(6.912)	(6.480)	(9.003)	(10.716)	(9.340)	(4.805)	(6.493)
Observations	1147	1147	211	211	411	411	308	308	217	217
R^2	0.384	0.436	0.414	0.439	0.372	0.449	0.441	0.477	0.325	0.354
Session FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Religion FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The dependent variable is the amount sent back by a receiver in a round × session. The analysis is based on the participants that at least played once with a different ethnicity in all the five rounds, i.e. 275 receivers. We further exclude the rounds where the receiver receives zero. Standard errors clustered at the individual level are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The geographical closeness and individual characteristics including age, gender, education, marital status, self-perceived relative wealth, and a dummy of being farmer are controlled.

Table A.9: OLS regressions explaining contribution levels in the public goods game with gender interactions)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	Contribution - All rounds			Contribution - First round		
One non co-ethnic	-1.431**	-1.181*	-1.040	-0.403	-0.211	-0.0639
	(0.634)	(0.670)	(0.647)	(0.902)	(0.970)	(0.945)
Two non co-ethnics	-0.689*	-0.252	0.0936	-0.229	0.136	0.592
	(0.358)	(0.426)	(0.448)	(0.398)	(0.520)	(0.592)
Three non co-ethnics	1.522	1.428	1.594	1.997	1.729	1.857
	(2.048)	(1.688)	(1.540)	(2.377)	(1.946)	(1.774)
Female	-0.185	-0.168	-0.147	-0.0381	-0.00520	0.0205
	(0.262)	(0.252)	(0.253)	(0.331)	(0.323)	(0.324)
One non co-ethnic x Female	-0.137	0.235	0.226	-1.244	-0.858	-0.803
	(0.912)	(0.923)	(0.895)	(0.904)	(0.973)	(0.947)
Two non co-ethnics x Female	0.239	0.192	0.0134	-0.157	-0.214	-0.434
	(0.379)	(0.368)	(0.379)	(0.501)	(0.493)	(0.504)
Three non co-ethnics x Female	-2.556	-1.881	-1.594	-2.537	-1.751	-1.301
	(2.211)	(1.871)	(1.723)	(2.541)	(2.088)	(1.876)
Sender		0.208	0.302		-0.00614	0.123
		(0.427)	(0.440)		(0.550)	(0.569)
Amount sent x Sender		0.0459***	0.0446***		0.0572***	0.0548***
		(0.0108)	(0.0110)		(0.0144)	(0.0147)
Share sent back x Receiver		1.184***	1.210***		1.380***	1.355***
		(0.380)	(0.375)		(0.474)	(0.462)
Constant	7.428***	6.197***	6.017***	5.768***	4.490***	3.912***
	(0.718)	(0.766)	(0.922)	(0.794)	(0.843)	(1.100)
Observations	2,445	2,445	2,445	489	489	489
R-squared	0.228	0.257	0.269	0.173	0.220	0.244
Individual controls			Yes			Yes

The dependent variable is the tokens contributed by each player in each round. The analysis is based on 489 out of 576 participants, after excluding problematic participants. Standard errors clustered at the group level, shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Session, round, and ethnicity fixed effects are controlled. The individual controls include age, gender, education, marital status, self-perceived relative wealth, a dummy of being farmer, and geographical closeness.

Table A.10: Linear probability model for the likelihood that *i* punishes *j* with gender interactions

	(1)	(2)	(3)	(4)
	Positive Contribution Gap		Negative Contribution Gap	
Own contribution	-0.016***	-0.016***	-0.005	-0.005
	(0.005)	(0.005)	(0.005)	(0.005)
Mixed group	0.016	0.016	-0.018	-0.008
	(0.045)	(0.055)	(0.039)	(0.049)
Mixed own ethnic.	-0.051**	-0.050	-0.013	-0.031
	(0.025)	(0.032)	(0.021)	(0.032)
Contri. Gap i over j	0.030***	0.030***	0.004	0.004
	(0.004)	(0.004)	(0.004)	(0.004)
Female	-0.049**	-0.048	-0.044**	-0.043
	(0.024)	(0.030)	(0.022)	(0.030)
Mixed group x Female		-0.001		-0.013
		(0.049)		(0.045)
Mixed own ethnic. x Female		-0.003		0.031
		(0.032)		(0.042)
Sender	-0.027	-0.027	-0.066	-0.066
	(0.056)	(0.057)	(0.049)	(0.049)
Amount sent x Sender	0.001	0.001	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Share sent back x Receiver	-0.029	-0.029	-0.026	-0.027
	(0.038)	(0.038)	(0.044)	(0.044)
Constant	0.521***	0.521***	0.470***	0.467***
	(0.118)	(0.121)	(0.123)	(0.127)
Individual controls	Yes	Yes	Yes	Yes
Observations	4,504	4,504	4,524	4,524

The dependent variable is whether a player punishes another player in a round×session. The analysis is based on 489 out of 576 participants, after excluding problematic participants. Positive contribution gap refers to the case where player *j* contributes no less than player *i*, vice versa. Standard errors are clustered at the group level, shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The round, ethnicity and session fixed effects and individual random effects are controlled. The individual controls include age, gender, education, marital status, self-perceived relative wealth, a dummy of being farmer, and geographical closeness.

Appendix 1.B Definition of Closeness

- For a pair of players (i,j), if i and j are from the same village group in the sessions running in the rural area or the same church in those in Jinghong city, we consider i and j are known to each other. Formally, if $S_i = S_j$ ($S_i, S_j \in \{VG1, ..., VG23, Church1, Church2\}$), i and j know each other.
- Closeness measures the probability that j and i know each other given the revealed information to i about j (T_j, including ethnicity and religion), i.e. $P_{j,i}(S_j = S_i | T_j)$
- In the trust game and the punishment part of the public goods game, the closeness of j for i is measured by:

$$closeness_{j,i} = \frac{\sum_{k \neq i}^{N} \mathbb{1}\{T_k = T_j\} \times \mathbb{1}\{S_k = S_i\}}{\sum_{k \neq i}^{N} \mathbb{1}\{T_k = T_j\}}$$

- In the contribution part of the public goods game, the closeness of the three players *js* (j_1, j_2, j_3) for i is

Table A.11: Linear probability model for the likelihood that *i* punishes *j* (excluding 3+1 groups)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Positive Contribution Gap				Negative Contribution Gap			
Own contribution	-0.017***	-0.017***	-0.017***	-0.017***	-0.003	-0.004	-0.003	-0.004
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Mixed group	0.009	0.034	0.025	0.032	0.002	-0.002	-0.007	-0.014
	(0.028)	(0.044)	(0.047)	(0.046)	(0.025)	(0.038)	(0.041)	(0.040)
Mixed own ethnic.	-0.048**	-0.048**	-0.043	-0.030	0.002	0.002	0.001	-0.002
	(0.021)	(0.021)	(0.027)	(0.026)	(0.023)	(0.023)	(0.022)	(0.026)
Contri. Gap i over j	0.031***	0.031***	0.031***	0.032***	0.003	0.003	0.002	0.006
	(0.004)	(0.004)	(0.004)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Mixed group x Gap				0.001				-0.006
				(0.009)				(0.008)
Mixed own ethnic. x Gap				-0.008				-0.002
				(0.009)				(0.008)
Sender		-0.002	-0.017	-0.002		-0.052	-0.070	-0.051
		(0.059)	(0.058)	(0.059)		(0.052)	(0.052)	(0.052)
Amount sent x Sender		0.001	0.002	0.001		0.002	0.002	0.002
		(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
Share sent back x Receiver		-0.014	-0.020	-0.013		-0.033	-0.046	-0.031
		(0.038)	(0.038)	(0.038)		(0.045)	(0.044)	(0.044)
Constant	0.341***	0.322***	0.494***	0.320***	0.241***	0.266***	0.455***	0.274***
	(0.090)	(0.103)	(0.124)	(0.102)	(0.081)	(0.098)	(0.127)	(0.097)
Individual controls			Yes				Yes	
Observations	4,204	4,204	4,204	4,204	4,236	4,236	4,236	4,236
Number of groups	441	441	441	441	446	446	446	446

The dependent variable is whether a player punishes another player in a round×session. The analysis is based on 454 out of 576 participants, after excluding problematic participants and groups with "3+1" composition. Positive contribution gap refers to the case where player *j* contributes no less than player *i*, vice versa. Standard errors are clustered at the group level, shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The round, ethnicity and session fixed effects and individual random effects are controlled. The individual controls include age, gender, education, marital status, relative wealth, a dummy of being farmer, and geographical closeness.

measured by:

$$closeness_{js,i} = \frac{1}{3} \sum_{m,2,3} \frac{\sum_{k \neq i}^{N} \mathbb{1}\{T_k = T_{j_m}\} \times \mathbb{1}\{S_k = S_i\}}{\sum_{k \neq i}^{N} \mathbb{1}\{T_k = T_{j_m}\}}$$

Chapter 2

Marriage, Migration, and Migration Policy: Evidence from Hukou Reform in China

2.1 Introduction

Do marriage prospects affect migration decisions? A substantial number of migrants every year bear large migration cost and migrate to more developed areas, searching for better income, public services, or amenities. An important, yet largely overlooked, driving force of migration is marriage prospects–the anticipatory payoff from having or finding spouses with high income, legal status, or access to local public goods. Intermarriage is important for migrants to overcome migration restrictions.[1] It is crucial to understand how merit-based migration policies contingent on skill or investment levels would shape migrant flows indirectly through marriage.

This paper answers two questions. First, what is the effect of marriage prospects on migration decisions? Second, what is the impact of merit-based migration policies on migrant flows, if we take marital gains and strategic spouse choices into account? To do that, I develop a dynamic migration and marriage model based on Choo and Siow (2006) and Dupuy (2021). The theoretical model shows that merit-based migration policies have negligible or even opposite impact on migrant composition. It is because migrants without qualified merits are indirectly affected by these policies through marriage. In addition, more lenient (stringent) policies towards high-skilled migrants would increase (decrease) the early marriage rate of high-skilled locals and reduce (increase) the degree of assortative matching on education. With Chinese data, I show that intermarriage opportunities drive 10% of the migration of singles aged 20-35 to large cities in 2000. This migration would increase by two times if migrants no longer face institutional barriers on access to local public services. Neglecting the indirect effect through marriage prospects, we

[1] Intermarriage is important for settlement. In 2008, 39% of permanent residency in the UK are granted for spouse settlement (Charsley et al., 2012). Intermarriage choices also respond to migration regulations. Amuedo-Dorantes, Arenas-Arroyo and Wang (2019) show that migrant/local marriage increases with enforcement of illegal immigration in U.S. and Adda, Pinotti and Tura (2020) find a reduction in intermarriage after the enlargement of E.U.

would substantially underestimate the number of migrants in total, especially those with less than high school education. To the best of my knowledge, this is the first study that investigates how merit-based migration policies shape migrant flows through marriage.

This paper starts with the model. I assume individuals live for several periods. In each period, singles and couples choose whether to migrate based on migration cost and the expected returns from wage, local benefits, and marriage. Then singles decide on whether and whom to marry. At the end, individuals can obtain local status - a permit to access local benefits - the ex-ante probabilities are determined by merit-based migration policies. Local status could refer to permanent residency in immigration or local hukou in internal migration in China. By marring spouses with local status, migrants without local status can have partial access to local benefits. I examine the predictions on the impact of relaxing merit-based policies. I show that including marriage reduces the positive impact on the migration of skilled migrants, but generates positive spillover effect on the migration of other migrants. On one hand, skilled migrants marrying locals are only mildly affected by the policies, and the potential spouses of skilled migrants are affected through indirect marital gains. On the other hand, competition reduces the marital gains of skilled migrants but increases those of other migrants. In addition to migration decisions, the relaxation of migration policies partial to skilled migrants generates strategic marriage responses. For example, it pushes skilled locals to enter early marriage with low-skilled migrants, delays the marriage between skilled migrants and low-skilled migrants, and reduces the degree of assortative matching on education.

I empirically study the Chinese case. The Chinese hukou system registers individuals to a city/county and rural/urban area, and set rigid criteria on hukou transition. The goal was originally to control migration and later to reduce fiscal burden. Individuals with local hukou in the urban area had access to large local benefits, including cheaper housing, public education, advantages in job search, etc. According to Gao, Yang and Li (2013), the social benefits of urban hukou accounted for 27% of HH disposable income in 2002 and 20% in 2007. Since 1997, large-scale hukou reforms were initiated by the central government to relax the criteria based on house purchase, talent programs, length of marriage with locals, and other aspects. The reforms differed across regions and over time. I exploit the rich variations in hukou reforms for identification using a narrative approach following Fan (2019). Reduced-form evidence shows strong positive correlations between the advancement of both types of reforms and the number of migrants.

To fit the reality, I divide China into 26 regions and include more age and education categories. The main data are repeated cross-sectional population census in 2000 and 2005 and the individual migration history from China Labor Dynamic Survey. I first estimate hukou conversion probability by individual characteristics and location using individual migration history and

policy variations. Then I estimate the utility parameters of the model based on predicted wage using migration and marriage choices in the population census. The estimated value of local benefits is equivalent to 22% of monthly income in 2005 in the urban area and around 50% in big cities.

Using the fitted model, I quantify the effect of intermarriage opportunities on migration decisions to large cities by shutting down the marriages with spouses from different locations (different hukou places). The number of migrants aged 20-35 in large cities decreases by 5.6% for men and 12.8% for women in 2000. One-third of the drops are driven by the hukou benefits that migrants enjoy in local/migrant marriages, and the other two-thirds are due to educational attainments and sex ratio. Consistent with the existing literature, marriage prospects are more important for women than for men.

In the second exercise, I analyze the counterfactual policy of granting migrants local hukou immediately. The results show that the number of migrants moving into large cities would increase substantially by 2.1 times for men and 1.7 times for women in 2000. This change can be decomposed into two parts, i.e. the increased incentives given spouse choices and within-household bargaining power unchanged, and the additional incentives that singles can get from the flexibility of choosing different spouses and bargain for welfare within couples. Neglecting the second part leads to the underestimation of migrant flows to large cities. The increase in migrant number would only be 1.2 times for men and 0.6 times for women. This implies an underestimation of the total migration of men by about 30% and of women by 40%. In terms of migrants by demographics, neglecting marriage adjustments misleads us to overestimate the inflow of highly educated migrants and underestimate the inflow of migrants with less than bachelor's degree. The direction of these changes above is aligned with the insights of the theoretical model.

The main contribution to the literature is threefold. First, this paper contributes to a recent literature studying the extent that marriage prospects affect migration decisions. Compared to Dupuy (2021), this paper provides a framework to identify the benefits contingent on local status by adding spatial heterogeneity and dynamics in migration and marriage decisions. I show that intermarriage opportunities are important in migration for either gender, after embedding the indirect gains from migration success through marriage prospects. Second, to the best of my knowledge, this is the first study to investigate how marriage adjustments shape the impact of merit-based migration policies on migrant flows. I show both theoretically and empirically the potential bias of neglecting marriage prospects in the evaluation and design of merit-based migration policies, providing important policy implications.

The remainder of the paper is organized as follows. Section 2 explains the contribution to the related literature in more details. Section 3 introduces a general framework and calibrates

the impact of policy relaxation on migration flows. Section 4 introduces the hukou system in China, the data, and the descriptive statistics. Section 5 explains the structural estimation and discusses the identification. Section 6 reports the estimation results. Section 7 quantifies the effect of marriage prospects on migration decisions and studies counterfactual policies. I conclude the paper in section 8. In addition, I provide a summary of notations at the beginning of the Appendix.

2.2 Contribution to the related literature

This paper speaks to three strands of literature. The first line of works studies the determinants of migration decisions, including direct economic incentives (Borjas, 1987; Kennan and Walker, 2011), amenities (Bayer, Keohane and Timmins, 2009*a*; Sullivan, 2016), and marriage/family demand (Rosenzweig and Stark, 1989; Edlund, 2005; Smith and Thomas, 1998; Nie and Xing, 2011; Dupuy, 2021). Marriage-driven migration receives much less attention than migration driven by economic earnings, and this literature tend to focus on migration because of marriage (Rosenzweig and Stark, 1989; Nie and Xing, 2011; Weiss, Yi and Zhang, 2018; Ahn, 2018), and mobility tied to partners (Smith and Thomas, 1998). Marriage prospects which implies the uncertainty of searching for spouses at destinations, however, are seldom studied, despite the evidence showing that females cluster in cities in search of males with higher income (Edlund, 2005) and higher meeting rates (Gautier, Svarer and Teulings, 2010). The lack of studies is mainly due to two reasons. First, marriage prospects only become important in the past several decades. On one hand, not many women migrated before marriage because of the difficulties in finding jobs. On the other hand, arranged marriage used to be the tradition especially when couples rely economically on the parents/big family. Second, it is difficult to disentangle marriages prospects from other migration incentives. Dupuy (2021) skips the division of how couple meet and quantifies the share of total marital gains in migration surplus. This paper contributes to the literature by quantifying the effect of marriage prospects on migration decisions.

Second, this paper also contributes to the literature on marriage matching. An important subject along this literature is the determinants of observed marriage matching patterns (Choo and Siow, 2006; Choo, 2015; Zha, 2018; Bisin and Tura, 2019; Banerjee et al., 2013). The seminal paper of Choo and Siow (2006) provides a static marriage model to estimate a non-parametric marriage matching function of individual characteristics with spillover effects. Another line of works study the interaction between marriage choices and other important life-cycle decisions such as education investment (Chiappori, Dias and Meghir, 2018; Raiber, 2018) and migration decisions (Dupuy, 2021). Dupuy (2021) develops a static marriage and migration model based on Choo and Siow (2006) and Chiappori, Dias and Meghir (2018) and estimate a non-parametric

marriage matching and migration function to study the extent that people migrate in order to marry-up. This paper extends the two-region static model of Dupuy (2021) by modeling the process of market clearing using "dynamic" migration and marriage decisions in a multi-region setting. These differences are crucial to identify individual gains from changing hukou status and intermarriage. These gains are important for policy counterfactuals such as hukou reforms.

The third strand of the literature studies the impact of migration/hukou policies on migration (Lessem, 2018; Llull, 2018; Mayda et al., 2018; Bertoli, Dequiedt and Zenou, 2016; Docquier and Rapoport, 2004; Fan, 2019; Kinnan, Wang and Wang, 2018; Colas and Ge, 2019) and intermarriage decisions (Weiss, Yi and Zhang, 2018; Ahn, 2018; Han, Li and Zhao, 2015; Adda, Pinotti and Tura, 2020; Ahn, 2018; Nie and Xing, 2011; Amuedo-Dorantes, Arenas-Arroyo and Wang, 2019). While some works including Weiss, Yi and Zhang (2018), Han, Li and Zhao (2015) and Nie and Xing (2011) exploit the variation of migration policies towards children and migrant spouses in intermarriages, I focus on merit-based migration policies that regulate migrants' legal/hukou status independent of marriage. Different from Adda, Pinotti and Tura (2020), Ahn (2018), and Amuedo-Dorantes, Arenas-Arroyo and Wang (2019) that also study merit-based migration policies, I focus on the policy impact on migration decisions; different from those studies that investigate migration decisions, I consider the interaction between marriage and migration decisions. Also note that different from Tombe and Zhu (2019*a*) and Fan (2019) which treat hukou restrictions as universal, homogeneous migration cost for migrants, I take into account the privilege of migrant spouses in intermarriages. By adding this interaction and the extended privilege, I illustrate the unintended impact of migration policies on migrant flows using theoretical calibration and empirical counterfactuals. The structural model allow me to analyze the counterfactual policy of removing hukou restrictions taking into account marriage choices.

This paper is also related to works on hukou policies, such as Sieg, Yoon and Zhang (2020), Gai et al. (2021), Fan (2019) and Zhang, Wang and Lu (2019). This paper digitizes spouse-based hukou reforms following the spirit of Fan (2019) and this data can also be used in future studies related to intermarriage.

2.3 Simple two-region two-period model

I develop a two-region dynamic migration and marriage model to illustrate the impact of migration policies on migrant flows and marriage decisions. Individuals live for two periods. In each period, forward-looking individuals first choose whether to migrate to the other region, then decide whether and whom to marry under transferable utility framework if they are single, and finally wait for the realization of local status. There are certain local benefits associated with

local status, and migrants can access these benefits either by obtaining local status themselves or through marriage. Merit-based migration policy determines the probability that migrants get local status with their skills. Migrants without local status can get partial access by marrying those with local status. Migration policies thus directly affect migration and intermarriage incentives and indirectly generate equilibrium feedback effects of marriage markets.

2.3.1 Types

Consider two regions, receiving (r) and sending (s) region. It could be urban (receiving region) and rural (sending region) within a country, or a developed country as the receiving region and a developing country as the sending region. Individuals live for two periods. Denote $a \in \{1,2\}$ as age category, and individuals with different age categories always coexist. Denote t as the time period. In each period t and each location, there are single men and women of age category $a = 1$ entering the model as natives and entitled with local status $h \in \{r,s\}$ same as the region. The local status can change after migration. Individuals also differ in skill level $e \in \{h,l\}$, high or low. Denote m_{it} as the type of any man i at time t (f_{it} as the type of any woman j): it is a combination of the skill level e_{it}, the place with local status h_{it}, and age category a_{it}, i.e. $m_{it} = (e_{it}, h_{it}, a_{it})$.

Assume each man can be married to one and only one woman. To model migration and marriage decisions, assume the state vector of any man i (or woman j) at time t includes individual type, initial spouse type $\overline{f}^o_{i,t}$ (or $\overline{m}^o_{j,t}$, note that $\overline{f}$ can be zero, meaning staying single), initial location $d^o_{i,t}$, and idiosyncratic tastes ε_{it} (or ε_{jt}). The idiosyncratic tastes further include idiosyncratic location tastes $\varepsilon^d_{it} = (\varepsilon^s_{it}, \varepsilon^r_{it})$ satisfying Gumbel distribution and idiosyncratic spouse-type preference $\varepsilon^{\overline{f}|d}_{it}$ conditional on location choice d. Assume the idiosyncratic spouse-type preference is only realized after location choice. As in Choo and Siow (2006), the idiosyncratic spouse-type preference is additively separable and independently drawn from Gumbel distribution. These idiosyncratic preferences are observed by other individuals but not the researcher. To simplify notation, denote s as the vector of state variables excluding the idiosyncratic tastes: $s_{it} = (m_{it}, d^o_{i,t}, \overline{f}^o_{i,t})$ (or $s_{jt} = (f_{jt}, d^o_{j,t}, \overline{m}^o_{j,t})$).

2.3.2 Choices

Assume migration is unilaterally from the sending region s to the receiving region r, i.e. natives and migrants with local status in r will not migrate to s, but migrants without local status in r can return to s.[2] Once married, couples make decisions jointly and have a joint idiosyncratic

[2] This is because the majority of migration flows is from less developed areas (s) to more developed ones (r). Bilateral movement is allowed in the empirical analysis.

location taste.

To simplify notation, I remove individual subscripts from all the variables concerning choices and observed state variables. I also remove time subscripts from choice and observed state variables if the time subscripts are subscripts or superscripts of other variables. For example, $c_t^{d_{it}|d^o_{i,t}}$ is replace by $c_t^{d|d^o}$, and $\varepsilon^{d_{i,t+\Delta t}}_{i,t+\Delta t}$ is replaced by $\varepsilon^{d}_{i,t+\Delta t}$ since ε is neither a choice nor an observed state variable.

In each period t, each man i (and woman j) makes the migration decision after observing wages, migration policies, local benefits, migration cost, prospects of regional marriage markets, and idiosyncratic location tastes. The objective is to maximize the expected discounted utility through location choice $d_t \in \{s, r\}$.

$$\max_{d_t} \sum_{\Delta t=0}^{2-a>0} \beta^{\Delta t} E(u^{m,\overline{f}|d}_{i,t+\Delta t} - c^{d|d^o}_{t+\Delta t} + \varepsilon^{d}_{i,t+\Delta t} + \varepsilon^{\overline{f}|d}_{i,t+\Delta t})|d_t, s_t, \varepsilon^{d}_{it}]$$

where u is man's deterministic utility from staying single or certain type of marriage in certain location at certain period and c is migration cost. The problem of woman j is similar, and denote v as woman's deterministic utility from staying single or certain type of marriage.

After location choices, singles look for spouses within the regional marriage market under transferable utility framework to maximize the expected utility. Taking type m_t single men as an example. The problem can be written as to maximize the current utility after location choice plus the expected discounted utility given potential status change of spouses:

$$\max_{\overline{f}_t} u^{m,\overline{f}|d}_{it} + \varepsilon^{\overline{f}|d}_{it} + \sum_{\Delta t=1}^{2-a>1} \beta^{\Delta t} E(u^{m,\overline{f}|d}_{i,t+\Delta t} - c^{d|d^o}_{t+\Delta t} + \varepsilon^{d}_{i,t+\Delta t} + \varepsilon^{\overline{f}|d}_{i,t+\Delta t}|d_t, \overline{f}_t, s_t, \varepsilon_{it})$$

The single-household utility of marriage depends on current utility from wages, benefit extension, and systematic marriage preferences, and expected discounted utility in the future. Assume only individuals with local status or local spouses can access certain local benefits.[3] In the equilibrium, the couples agree on how to divide utility after marriage (u and v) when they get married. No one has incentives to change marital status (single/married) and there are no two individuals who want to switch partners and match together.

At the end of each period t, migrants obtain local status with probability k^d_e that depends on their skill levels. Denote k^d_e as merit-based migration policies. I will focus on the policies in region r and abstract from policy component in region s. The migration policies favor high-skilled migrants. The heterogeneity in skill levels is important to illustrate the heterogeneous marriage

[3] In the case of immigration, local status can be permanent residency/citizenship, and then the local benefits are the benefits associated to permanent residence permit. In the case of internal migration, local status is the identity used to restrict migrant access to local public services, for example, the hukou place in China.

responses and policy spillover effects on migration decisions. This skill-based favoritism is an example of the selective feature of migration policies, and the model insights can be extended to wealth- or employment-based policies. Divorce and human capital investment are not considered. The transition function of state variables of a man i (similar for a woman j) satisfies:

$$TF(m_{t+1}, \overline{f}^{o}_{t+1}, \varepsilon_{i,t+1} | m_t, \overline{f}_t, d_t, k^d_e, \varepsilon_{it}) = TF(m_{t+1}|m_t, d_t, k^d_e) TF(\overline{f}^{o}_{t+1}|\overline{f}_t, d_t, k^d_e) TF(\varepsilon_{i,t+1}|\varepsilon_{it})$$

where $TF(\cdot)$ is the transition probability. The transition of m and f for those without local status only depends on regional migration policies.

This setup implies two underlying assumptions. First, idiosyncratic marriage preferences does not affect individual migration decisions. Second, if couples get married before migration in reality, I either assume they choose to get married at home at $a = 1$ and then migrate at $a = 2$ or assume they will make the same decision if they migrate first, depending on the time gap.

Timeline

The timeline of period t can be summarized as follows:

- 1. Idiosyncratic location preference ε^d_{it} of man i (and ε^d_{jt} of woman j) is realized, and then men (and women) choose whether to migrate at a cost $c_t^{d|d^o}$.
- 2. Spouse-type preferences $\varepsilon^{\overline{f}|d}_{it}$ and $\varepsilon^{\overline{m}|d}_{it}$ (including single preference) realize. Then within each location, all singles (locals and migrants) form households until marriage markets clear.
- 3. Individual/household utility is realized.
- 4. Migrants get local status with probability k^d_e that depends on skill levels e_{it}.

$\varepsilon^d_{it}, \varepsilon^d_{jt}$	$\varepsilon^{\overline{f}|d}_{it}, \varepsilon^{\overline{m}|d}_{jt}$		$m_t, f_t \rightarrow m_{t+1}, f_{t+1}$
Location preference Migrate or stay	Spouse preference Marriage formation	Utility realization	Transition of local status

2.3.3 Instantaneous single/household utility after migration

The household utility is composed of deterministic utility and idiosyncratic spouse-type preferences. The deterministic utility comes from wage, local benefits, and match-specific marriage preference. Marriage affects utility in three ways. First, marriage affects individual

utility from own income through spouse income. The economies of scale in public consumption such as the investment on children and housing imply that individual marginal utility from income increases with spouse income, while specialization in labor provision implies that spouse income substitutes for own income. Second, migrants with local spouses have partial access to local benefits. The utility of staying single or having spouses exiting the model is computed in the same way but excluding the part related to spouses. Third, apart from these economic components, marriage between partners with different social backgrounds could entail additional cost.

Assume for any **match** (m_t, f_t), households choose the optimal allocation of budget between private and public consumption. To satisfy transferable utility property (Chiappori, Dias and Meghir, 2018), assume the deterministic utility from household consumption is given by:[4]

$$\frac{(w_t^{m|d} + w_t^{f|d})^2}{4}$$

where $w_t^{m|d}$ and $w_t^{f|d}$ are the type-specific wages of type-m men and type-f women in region d. This functional form pushes towards positive assortative matching on income, because individuals benefit from their spouses' income through public consumption.

The deterministic utility from local benefits is a function of local benefits ϕ_d and local status of the couple. Due to the regulation of regional government in the receiving region, migrants can only enjoy local benefits $\phi_r > 0$ after obtaining local status. Normalize the benefits in the sending region ϕ_s to be zero. Those with a local spouse have **partial access** to the benefits of the spouse with the ratio equal to $0 < b < 1$. The partial benefits come from two channels. First, migrants face lower criteria on local status by marrying locals. Second, migrants can enjoy some benefits of local spouses without local status, for example, subsidized housing and children's education in China or immediate access to resident permit in the EU.

Let $B(\mathbb{1}_d(m_t) + \mathbb{1}_d(f_t))$ be household access to local benefits, where $\mathbb{1}_d(m_t)$ and $\mathbb{1}_d(f_t)$ are dummies of whether the type-m man or the type-f woman has the local status in location d. Let $B(0) = 0$, $B(1) = 1 + b$, and $B(2) = 2$. $B(1)$ means local/migrant marriage, and the migrant has

[4] This functional form of consumption utility satisfies the transferable utility property (Chiappori, Dias and Meghir, 2018) and supermodularity utility in wage. Transferable utility framework guarantees the unique marriage matching equilibrium given individual location choices. Supermodularity utility in wage leads to positive assortative matching on skills that is widely observable in practice. The micro-foundation follows that of Low (2017). Assume household maximizes $\max_{y_t^{m|d}, y_t^{f|d}, Q_t^d} (y_t^{m|d} + y_t^{f|d})Q_t^d$ subject to the budget constraint $y_t^{m|d} + y_t^{f|d} + Q_t^d = w_t^{m|d} + w_t^{f|d}$, where $y_t^{m|d}$ and $y_t^{f|d}$ are private consumption of a type-m man and a type-f woman in a (m, f) match. $w_t^{m|d}$ and $w_t^{f|d}$ are the individual wages, and Q_t^d is household public consumption. The solution of the optimization problem is $y_t^{m|d} + y_t^{f|d} = Q_t^d = \frac{w_t^{m|d} + w_t^{f|d}}{2}$. Thus, the maximized joint household utility under the budget constraint can be characterized by $(w_t^{m|d} + w_t^{f|d})^2/4$.

partial access to local benefits. Thus, the utility from local benefits is

$$B(\mathbb{1}_d(m_t) + \mathbb{1}_d(f_t))\phi_d$$

This pushes towards negative assortative matching on local status, because only migrants gains from the partial access to local benefits by marrying locals.

Thus deterministic component of instantaneous household utility $\pi_{d,t}^{mf}$ is the sum of deterministic utility from consumption and that from local benefits:

$$\pi_t^{mf|d} = \frac{(w_t^{m|d} + w_t^{f|d})^2}{4} + B(\mathbb{1}_d(m_t) + \mathbb{1}_d(f_t))\phi_d + \tau^{mf|d}$$

where $\tau^{mf|d}$ is match-specific marriage preference including disutility of intermarriage with respect to homogamy. Denote $\pi_t^{m0|d}$ and $\pi_t^{0f|d}$ as the instantaneous single utility of type-m men and type-f women at period t in region d.

To allow heterogeneous individual choices and continuous comparative statics, I add an idiosyncratic location preference ε_{it}^d (or ε_{jt}^d) before migration decision and an idiosyncratic spouse preference $\varepsilon_{it}^{\overline{f}|d}$ (or $\varepsilon_{it}^{\overline{m}|d}$) before marriage decision, independent from deterministic utility.

2.3.4 Equilibrium

The stationary equilibrium can be solved using fixed point algorithm, as long as we impose parametric assumptions on marital surplus and distribution assumptions on idiosyncratic preferences. The intuition is that given migration decisions of different types of men and women, the composition of marriage markets is determined and then the marriage matching patterns by individual type are uniquely pinned down. On the other way around, expecting marriage matching patterns, expected migration returns are determined and migration patterns by individual type are uniquely pinned down. Note that in marriage market equilibrium under transferable utility, the division of the deterministic marital surplus between husbands and wives is endogenous. I relate this division as bargaining power afterwards. In addition, migration decision is made based on expectations over marriage markets, but this expectation is affected by the migration decisions of others.

The equilibrium can be characterized by migrant flows and regional marriage pattern of individuals by type. I follow the iteration procedure in Dupuy (2021) to solve the marriage matching equilibrium as explained in section 2.A. To prove the equilibrium existence, I first extend the mapping function of choice probabilities to the 0/1 boundaries and make it continuous by construction, then I use Brouwer's fixed point theorem to prove the equilibrium existence, and in the end show that the equilibrium is not on the boundary (details in section 2.C).

Marriage market equilibrium

A marriage matching equilibrium is defined as 1) a set of probabilities that men and women with certain characteristics match with each other or stay single and 2) the individual deterministic choice-specific utility. Under transferable utility framework, the equilibrium given individual location choices maximizes the social welfare. In the stable matching equilibrium, individuals who enter marriage would strictly prefer current match to being single, and there are no two individuals who strictly prefer being matched together to the current choice (Chiappori, Salanié and Weiss, 2017). This equilibrium is unique given location choices if we assume the population is large enough to treat individuals of each type as a continuum.

When men and women form couples, instead of negotiating about how to divide instantaneous utility in each time and each region, we can simply assume they agree on the way of dividing the total expected marital surplus after discounting. This simplifies the equilibrium computation with the underlying assumption that the bargaining power is the same over time and across scenarios.

Denote $\Pi_t^{mf|d}$ as the expected discounted stream of utility conditional on optimal behaviors of couples (m, f) at period t in region d after migration decision. The marriage equilibrium satisfies the following condition following the literature:

$$U_t^{mf|d} + V_t^{mf|d} = \Pi_t^{mf|d} \tag{2.1}$$

where $U_t^{mf|d}$ is the expected discounted utility of type-m men and $V_t^{mf|d}$ is that of type-f women in a match (m, f). $U_t^{m0|d}$ and $V_t^{0f|d}$ are the corresponding expected discounted utility of staying single.

Besides the above equality equation, the marriage market clearing conditions should also be satisfied in the equilibrium. Denote $p_t^{\overline{f}|m,d}$ as the probability of type-m men that choose spouse type $\overline{f}$. $q_t^{\overline{m}|f,d}$ is the corresponding choice probability of type-f women. Marriage market clearing conditions require the number of type f women demanded by type m men to be equal to the number of type m men demanded by type f women:

$$p_t^{\overline{f}|m,d} N_t^{m|d} = q_t^{\overline{m}|f,d} N_t^{f|d}$$

where $N_t^{m|d}$ is the number of type-m single men in location d after migration and $N_t^{f|d}$ is the number of type-f single women. These numbers are determined by individual migration decisions.

Migration equilibrium

The migration equilibrium is equivalent to a fixed-point problem of location choice probabilities of different types of individuals. Assume the population is large enough to analyze the aggregate choice probabilities each as a continuum. The location choice probabilities uniquely determine the ex-ante expected utility for each type of individuals in each location, because the marriage market equilibrium is unique. The expected utility in each location also uniquely determines the location choice probabilities of each type of individuals.

The migration probability of type-m men $p_t^{d|s}$ ($q_t^{d|s}$ for type-f women) equals to the exponential of choice-specific expected utility divided by the sum of the exponential of expected utility of all the choices in the choice set. For example, the ex-ante probability of type-m single men to migrate from region s to region r

$$p_t^{d|s} = \frac{e^{log(\sum_{\bar{f}_t} exp(U_t^{m\bar{f}|r}))-c}}{e^{log(\sum_{\bar{f}_t} exp(U_t^{m\bar{f}|r}))-c} + e^{log(\sum_{\bar{f}_t} exp(U_t^{m\bar{f}|s}))}} = \frac{\sum_{\bar{f}_t} exp(U_t^{m\bar{f}|r} - c)}{\sum_{\bar{f}_t} e^{U_t^{m\bar{f}|r}-c} + \sum_{\bar{f}_t} e^{(U_t^{m\bar{f}|s}}}$$

Comparative statics of merit-based migration policies

Merit-based policies directly affect migrant access to local benefits by changing their chance of getting local status independent of marriage. Marriage further shapes the policy impact on migration incentives in three ways. First, household utility from intermarriage and marriage between migrants changes given migrant partial access to local benefits in marriage with spouses holding local status. Second, migrants change the interests in marriage and potential spouses due to the change in household utility mentioned above. Third, the previous changes in migration and marriage choices generate an equilibrium feedback effect, affecting everyone in the marriage markets of two regions. In the example below, I calibrate the model to derive comparative statics of migration rate and dynamic marriage responses with respect to a merit-based migration policy favoring the high-skilled labor through k_h^r.

There are three predictions. First, when migration policies become more lenient toward high-skilled migrants, the number of low-skilled migrants increases as well. It means if policy makers want to control migrant composition through selective migration policies, the effectiveness will be largely reduced by marriage. Second, high-skilled migrants who are directly affected by the policy change tend to postpone marriage, while high-skilled locals who are close substitutes enter marriage earlier to avoid competition in the future. Third, the degree of positive assortative matching (PAM) on education decreases in region r because the high-skilled intermarriage switch to intermarriage between high-skilled locals and low-skilled migrants and marriage between migrants with different levels of skills. If migration policies become more lenient for low-skilled

migrants, we still observe the same pattern of migration rate and intermarriage rate but the opposite pattern of strategic marriage rate of low-skilled locals and PAM on education.

To derive the above predictions, I calibrate the model by assuming higher wages and skill share in region r.[5] The default transition probability is 0.5 for the high-skilled migrants ($k_h^r = 0.5$) and 0.2 for the low-skilled ($k_l^r = 0.2$). I abstract away from gender wage gap and sex ratio imbalance because the predictions still hold.

The comparative statics include two parts. The first part shows the migration rate for a given migration policy k_h^r if marriage is included or not, corresponding to the total policy effect of three channels due to marriage. The second part shows the migration rate if marriage responses are included or not, corresponding to the policy effect of the last two channels due to marriage.

Figure C.1: Difference in migration by inclusion of marriage

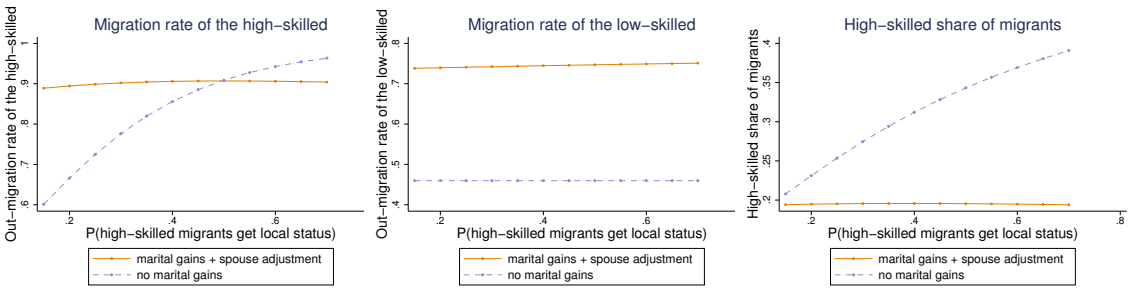
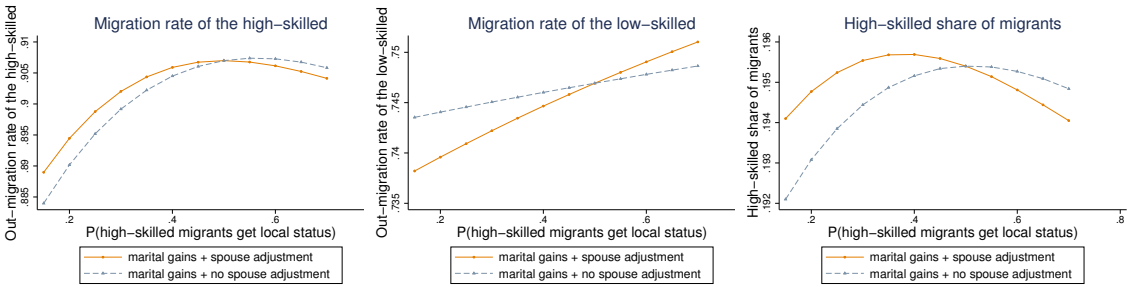


Figure C.1 shows the change in migration rate in response to change in k_h in region r. The x-axis is the probability that a high-skilled migrant can get local status. The variables at y-axis are the migration rate of high-skilled individuals in the sending region, that of low-skilled population in the sending region, and the skill share of all the migrants. Purple line refers to the case without marriage, and the orange is the case with marital utility and marriage market equilibrium. The figure shows that skill-biased migration policies have a limited impact on migrant composition. Marital utility is an important part of migration incentives. Marriage helps migrants to enjoy higher levels of consumption and access local benefits through intermarriage. When k_h increases, it moderately affects the migration rate of high-skilled individuals for three reasons. First, some of them already have partial access to local benefits through intermarriage. Second, the competition between high-skilled locals in the marriage market increases. Third, high-skilled individuals become more attractive in the sending region. Figure C.1 demonstrates the bias of using migration models where marital utility is neglected.

In Figure C.2, the green dashed lines depict the change in migration if individuals cannot

[5] The parameters are as follows. $\phi_r = 2$, $b = 0.7$, $c = 3$, and $\tau^{mf} = -3$ for intermarriage. The initial population of high-skilled men, high-skilled women, low-skilled men, low-skilled women in region r are 0.5, 0.5, 1, and 1, and the initial population following the same order in region s are 0.4, 0.4, 2, and 2. The wages in region r are 3, 3, 2, and 2, and the wages in region s are 2, 2, 1, and 1.

Figure C.2: Impact on migration due to marriage responses (default policy is 0.5)



adjust spouse choices to the change in migration policy k_h, while the orange line is the same as before but more observable. The x-axis and y-axis are the same as those in Figure C.1. We can see that the policy impact without spouse adjustment is in the middle of the policy impact without marital utility and that with marital utility and spouse adjustment. Neglecting strategic marriage responses, we would over-predict the positive impact on high-skilled migration and under-predict that on low-skilled migration. Low-skilled migrants could indirectly benefit from the increased marriage with high-skilled migrants and different types of locals. Figure C.2 corresponds to the counterfactual computed using reduced-form estimates from regressions of individual migration decisions over migration policies.

The comparative statics of marriage rate and marriage matching pattern are shown in the appendix 2.B.

Summary of results

It is important to embed marital utility and marriage responses in the analysis of migration and migration policies. Otherwise, we would over-predict the effectiveness of merit-based migration policies in attracting selective migrants with talents or wealth and shaping migrant composition. The theoretical model illustrates this using the example of a migration policy partial to high-skilled migrants. I compare the migration of individuals from the sending region in three cases: without marital utility, with marital utility but not allowing for changes in spouse choices, and with marital utility and marriage market equilibrium. The calibration results show that the policy impact on high-skilled migration decreases over the three cases for two reasons. First, the fact that high-skilled migrants use intermarriage to partially access local benefits reduces the their migration response to migration policies. Second, the increased competition in the marriage market further reduces the effect. In the meanwhile, the policy impact on low-skilled migration increases over the three cases also for two reasons. First, low-skilled migrants indirectly benefit from the marriage with high-skilled migrants. Second, more high-skilled migrants and different types of locals are willing to marry low-skilled migrants.

2.4 Background, data, and descriptive evidence

The empirical analysis uses Chinese data for three reasons. First, the institutional background is suitable because of the different benefits between locals and migrants and the regulated transition from migrants to locals. Second, there are rich variations in migration policies across regions and over time, and these policies are more comparable than the immigration policies of different countries. Third, Chinese migration and marriage data are representative, an advantage of internal migration. In this section, I introduce the hukou system, the data, and some descriptive evidence on policy variations and migrant flows.

2.4.1 Hukou system and hukou reforms

Hukou benefits

Mainland China has a household registration system called hukou system. This system registered individuals to a specific city or county and to rural or urban status, called hukou place, usually that of the parents.[6] Urban hukou are associated with considerable benefits, such as subsidized housing, cheaper medical services and public education, job opportunities in state-owned enterprises or the government, and other benefits.[7] According to Gao, Yang and Li (2013), the social benefits of urban hukou accounted for 27% of HH disposable income in 2002 and was just 1% for rural hukou. The geographical difference in hukou benefits is also large due to the varying quality and price of benefits above. Though the large benefits of urban hukou attracted migrants to settle down in cities, the difficulty imposed by hukou restrictions was a major reason of low migration rate in China before the large-scale hukou reforms.

Hukou reforms

After 1958, hukou system was rigid and used to control rural-to-urban migration, push down food prices, and subsidize urban residents with welfare benefits. The government set strict barriers on hukou transfer (urban to urban) and conversion (rural to urban) to control migration and migrant/local marriages. The hukou transition was mostly restricted to public sector employers and by quota. In 1977, the central government forbade rural individuals with urban spouses from moving to urban areas and they had to register their children as rural

[6] There was additional restriction that only allowed newborns to follow the hukou of mother, in order to limit migration through marriage (Han, Li and Zhao, 2015). This restriction was relaxed in 1998.

[7] Individuals with rural hukou have the rights of using land, but the price of agricultural products was low. Land allocation was largely settled in 1998 and invariant to the change in household composition. There are some exceptions. For example, some works document the impact of land insecurity on internal migration in China (Giles and Mu, 2018; De La Rupelle et al., 2009).

population. The restricted hukou transition significantly hindered internal migration in China.[8]

Since early nineties, the State Council and the Ministry of Public Security initiated large-scale hukou reforms to encourage the economy and meet political incentives (Peng, Zhao and Guo, 2009). Provinces decided the advancement of the reform within the designated boundary given not violating the spirit of the central government. Prefecture-level governments then set separate criteria on migrant access to local hukou. One branch of the criteria was based on investment, home purchase, employment, and talent programs (Zhang, Wang and Lu, 2019). Another branch of the criteria conditional on having local spouses was based on length of marriage, length of residence, age, and other requirements. These rich geographical and time variations allow me to document the progress of hukou reforms using the narrative approach in Fan (2019).

2.4.2 Data

This subsection briefly introduce the four types of data used in this paper: prefecture-level yearly data on hukou reforms, repeated cross-sectional Census data with information on migration and marriage choices, China Labor-force Dynamic Survey 2012-2016 containing individual migration history and hukou transition, and statistical yearbooks with information on regional characteristics.

Merit-based hukou reforms

Following the initiation of the central government, provinces and prefectures relaxed the criteria on hukou transition based on employment, investment, housing, and talent programs.These reforms are independent of whether having local spouses. Fan (2019) categorized prefecture-level merit-based reforms in 1997-2010 into indexes of 0-3, separately for city centers and towns. 0 means the migration policy is the most strict, while 3 is the most relaxed one. These indexes are based on employment and housing and do not differentiate Hukou reforms for skilled and unskilled migrants for simplification.[9] Thus I allow the heterogeneous policy impact on hukou transition by estimating group-specific parameters. The distribution of merit-based hukou reforms in 2000, 2005, and 2010 is summarized in Figure D.3. The reforms started faster in more developed areas due to the increasing labor demand but then advanced slower due to congestion

[8] Tombe and Zhu (2019*a*) show that in 2000 the average cost of moving from rural to urban areas within the same province approximates around 67% of the real income, and the cost is larger for across-province migration. Hukou restriction was a major part of this estimated cost.

[9] A potential concern is the bias due to the difference in reform advancement between skilled and unskilled migrants. Using the category-specific indexes in Zhang, Wang and Lu (2019), I find that the hukou reforms based on talent programs for the years 2000-2013 are highly, positively correlated with those based on employment and housing at that period.

and pollution problems (Fan, 2019). [10]

0	only public sector employers can obtain
1	purchasing an apartment above certain size or value
2	legal stable residence or contributing to the social security for $>$ 5 years
3	contributing to the local social security for $\leq$ 5 years

Table D.1: Merit-based hukou reform index

Spouse-based hukou reforms

Besides merit-based reforms, the government also relaxed the conditions of hukou transition for migrants with local spouses, based on length of the marriage, length of residence, age, stable housing, and income. For example, in 2001, an individual could obtain Beijing hukou if his or her marriage with a local was longer than ten years and he or she was above 45 years old. Besides these conditions, each region had a quota restricting the total number of registered population. I collect prefecture-level spouse policies in 1997-2010 and categorize them based on the criteria in Table D.2. These criteria were the most restricted in the big cities such as provincial capitals and provincial municipalities. The distribution of spouse-based hukou reforms in 2000, 2005, and 2010 is summarized in Figure D.3.[11]

0	marriage$\geq$10 years + age/quota restriction
1	residence/marriage $\geq$10 years, or 5 years$\leq$ minimum residence/marriage $<$10 years + age/quota restriction
2	5 years$\leq$ minimal residence/marriage$<$10 years, or minimum residence/marriage $<$5 years + age/quota restriction
3	minimal residence/marriage $<$5 years
4	Legal stable residence plus/ stable income source/ no restriction

Table D.2: Local spouse-based hukou reform index

Figure D.3 shows the progress of merit-based hukou reforms and spouse-based hukou reforms in 2000, 2005, and 2010. There are more geographical variations in the merit-based hukou

[10] The correlation between the reform index and the regional characteristics is in appendix 2.H. The advancement of merit-based reforms is positively correlated with urbanization rate. The large cities had slower trend in the advancements compared to other cities, and the prefectures farther away from the ports have faster trends. I control for GDP per worker, urbanization rate, the population density, different trends associated with the distance to ports, and regional fixed effects to mitigate the selection in hukou reforms.

[11] The correlation between the reform index and the regional characteristics is in appendix 2.H. The advancement of spouse-based reforms is positively correlated with urbanization rate and log of GDP per capita. The large cities had slower trend in the advancements compared to the other cities, and the prefectures farther away from the ports have slower trends. I control GDP per labor, urbanization rate, the population density, different trends associated with the distance to ports, and location fixed effects to reduce the selection in spouse-based hukou reforms.

reforms than in the spouse-based reforms.[12]

Figure D.3: Distribution of reform relaxation in 2000, 2005 and 2010 (higher color intensity means more relaxed policies)

Statistical yearbooks

I use province-level yearly CPI from China Compendium of Statistics 1949-2008 to adjust the predicted wage in the structural estimation. 1998-2010 China City Statistical Yearbooks are used to construct regional GDP per worker, urbanization rate, population density, and distance to ports that are important for migration and reform advancement. The summary statistics are provided in Table G.4 of the appendix 2.G.

Census

I use the 1 percent sample of the 2000 Census and the 20 percent sample of the 2005 mini-Census (also called 2005 1 Percent Population Survey).[13] These population censuses contain information of each household member on demographics, marriage time, hukou place, place of residence, and years of leaving hukou place. 2000 Census also has information on birth province, while 2005 Census has information on wages. These census data are representative of the whole population but are repeated cross-sectional data. There is no information on hukou transition, so I use the information on hukou transition in the small panel data introduced below.

China Labor-force Dynamics Survey (CLDS)

CLDS is a national longitudinal data survey in China that started in 2012 with two-year gaps. There is information on individual and family demographics, birthplace, place of residence at age 14, current place of residence, current place of registration, past migration experiences, and past hukou transfers/conversions.

I combine the information in waves 2012, 2014, and 2016 to back out the annual place of residence and registration for each individual. I use this information to estimate individual probability of getting local hukou for a given policy in a given location. I focus on individuals aged 16-55 and migrating after 1995. The summary statistics of individual characteristics of the

[12] There are documents on spouse-based hukou reforms at both provincial level and prefecture level. The provincial capitals usually issued separate policies besides the provincial policies, but not all prefectures. For some prefectures, if no document is available, I assume they followed the provincial policy.

[13] The China Population Census are only available in 1982, 1990, and every five years since 1990. The access to the data of the year 2010 is restricted.

migrants used in estimation are in Table G.5 of the appendix 2.G. The share of migrants who obtained local hukou within fives of migration but not in the first year is small.

2.4.3 Descriptive statistics

Evolution of out-migration rate, intermarriage rate, and hukou reforms

Table D.3 shows the changes in merit-based hukou reform index (0-3), spouse-based hukou reform index (0-4), the intermarriage rate, and the percentage of individuals leaving the prefecture of registration in the hukou system. The computation of intermarriage rate and out-migration rate are based on individuals aged 20-60. The intermarriage rate is computed to be the share of marriage of couples from different birth provinces getting married in that year. The share is based on Census 2010 and thus could not take into account divorced couples. All four measures increase over time. With the expansion of hukou reforms, the theoretical calibration predicts the decrease of percentage of marriage between locally born individuals and ones born outside. The observed increase in intermarriage rate is due to the increased interaction between natives and migrants, even though the economic incentives of intermarriage decrease.

Table D.3: Evolution of out-migration, intermarriage, and hukou reforms over time

Year	MeritPolicy	SpousePolicy	Intermarriage	Out-migration rate
1997	0.01	0.06	4.16%	
1998	0.05	1.06	4.53%	
1999	0.31	1.85	4.93%	
2000	0.39	2.18	5.28%	4.58%
2001	0.49	2.80	5.81%	
2002	0.49	2.81	5.81%	
2003	0.64	3.24	6.14%	
2004	0.91	3.26	7.22%	
2005	0.95	3.33	7.40%	7.49%
2006	1.03	3.32	8.74%	
2007	1.13	3.44	8.89%	
2008	1.16	3.50	9.97%	
2009	1.38	3.54	11.04%	
2010	1.48	3.62	14.12%	20.62%

Empirical correlations between migrant flows and hukou reforms

In this part, I provide empirical evidence on the correlation between migration flows and hukou reforms. First, one index increase of merit-based hukou reforms is correlated with an around 30% percent increase in the number of migrants in large cities, while one index increase

of local spouse-based hukou reforms is correlated with a 10% increase in the number of migrants in large cities. Second, being single before migration makes the correlation between migrant flows and hukou reforms much stronger. The summary statistics of relevant variables in the regressions are in appendix C.1.

The first regression studies the correlation between hukou reforms and the number of migrants. I regress the log of the number of migrants aged 22-35 choosing prefecture d at year t over regional hukou reform indexes. 22-35 are the prime age for marriage and mostly excludes migration driven by education. I estimate the following specification:

$$\begin{aligned} log(n_{dt}) =& \alpha_0 + \alpha_1 MeritPolicy_{dt} + \alpha_2 MeritPolicy_{dt} \times BigCity_d + \alpha_3 SpousePolicy_{dt} \\ &+ \alpha_4 SpousePolicy_{dt} \times BigCity_d + \iota_t + \iota_d + X_{dt}\beta + \varepsilon_{dt} \end{aligned} \tag{2.2}$$

where d is the prefecture of destination, and t is the year of data taking values from $\{2000, 2005, 2010\}$. n_{dt} is the number of migrants aged 22-35 that migrate to prefecture d within five years. $MeritPolicy_{dt}$ is the average degree of the merit-based hukou reforms in prefecture d at year t and measures the correlation between merit-based reforms and migration. By average degree, for example, the value for year 2005 is the average of reforms in 2001-2005. $SpousePolicy_{dt}$ is the average degree of spouse-based hukou reforms. $BigCity_d$ is a dummy that equals one if location d is one of the 36 large cities.[14] This dummy allows for a differential effect of the reforms for big cities. The predicted evidence of migration policy relaxation can be better observed in big cities. ι_t and ι_d are year FE and prefecture FE. X_{dt} is a vector of regional characteristics in 1998-2000 interacted with time trend and used to control the selection of migration policies due to labor demand and resource availability. The regional characteristics includes the GDP per employed worker, urbanization rate, the population density, different trends associated with the distance to ports, and prefecture fixed effects. The results are in Table D.4. It shows that in big cities, the migration flows have a positive correlation with the relaxation of both merit-based reforms and spouse-based reforms. The negative correlation with hukou reform indexes in small cities may be due to the competition from the big cities. For example, if a big city and a small city both increase the hukou reform index by one, the big city may attract more population from the small city than the number of migrant inflows to the small city. The regional competition for migrants motivates the structural estimation in which individuals endogenously choose locations.

Next, I examine the correlation between migration policies and migration flows by marital status. The dummy "Single" is equal to one if a migrant was single before migration. The

[14] The 36 large cities include provincial capitals, provincial municipalities, and Qingdao, Dalian, Xiamen, Shenzhen, and Ningbo.

Table D.4: Correlation between hukou policies and the number of migrants by gender

	(1)	(2)
Dependent variable: log(number of migrants)		
Sample	Female	Male
MeritPolicy	-0.0746*	-0.119***
	(0.0417)	(0.0407)
MeritPolicy x BigCity	0.215*	0.267**
	(0.110)	(0.106)
SpousePolicy	0.0222	0.0664*
	(0.0380)	(0.0384)
SpousePolicy x BigCity	0.118**	0.116**
	(0.0494)	(0.0492)
Constant	4.458***	4.437***
	(0.216)	(0.241)
Year FE	√	√
Pref FE	√	√
Pref Chara.	√	√
Observations	783	783
R-squared	0.948	0.954

The results are based on individuals aged 22-35. Standard errors clustered at prefecture level are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The sample is restricted to the prefectures with information available.

specification is in equation (2.3).

$$\begin{aligned} log(n_{idt}) =& \alpha_0 + \alpha_1 MeritPolicy_{dt} + \alpha_2 MeritPolicy_{dt} \times BigCity_d + \alpha_3 MeritPolicy_{dt} \times Single_{it} \\ &+ \alpha_4 MeritPolicy_{dt} \times BigCity_d \times Single_{it} + \alpha_5 SpousePolicy_{dt} \\ &+ \alpha_6 SpousePolicy_{dt} \times BigCity_d + \iota_{it} + \iota_d + X_{dt}\beta + \varepsilon_{dt} \end{aligned} \tag{2.3}$$

I further separate migrants by education levels to study the heterogeneity in correlation. In the specification, I interact the single dummy with MeritPolicy and with the interaction of MeritPolicy and BigCity. Different time trends contingent on marital status before migration are controlled with the interaction between Single and FEs. The results are in Table D.5.[15] Marital status interacts with hukou reforms in two ways: enlarged marriage market at destinations or increased attractiveness of local hukou. The positive coefficients of the interaction term $MeritPolicy \times BigCity \times Single$ support the story that the relaxation of migration policy gives single migrants more incentives to migrate, except for men with (less than) high school education.

[15] The two missing observations in column (3) is due to the lack of highly educated migrants who married before migration and those who were single before migration in 2005 in the prefecture FangchengGang.

Table D.5: Correlation between migration policies and migration flows by marital status

	(1)	(2)	(3)	(4)
Variables	Dependent variable: log(number of migrants)			
Sample	HighEdu F	LowEdu F	HighEdu M	LowEdu M
MeritPolicy	-0.0799	-0.0739	-0.0947	-0.171***
	(0.0506)	(0.0479)	(0.0600)	(0.0451)
MeritPolicy x BigCity	0.0188	0.159	0.156	0.436***
	(0.131)	(0.119)	(0.160)	(0.110)
MeritPolicy x Single	-0.0732	0.0443	-0.0600	0.0670**
	(0.0463)	(0.0367)	(0.0499)	(0.0316)
MeritPolicy x BigCity x Single	0.401***	0.342***	0.396***	0.0836
	(0.0703)	(0.0668)	(0.0651)	(0.0528)
SpousePolicy	0.0138	0.00717	-0.00350	0.0644*
	(0.0330)	(0.0372)	(0.0378)	(0.0384)
SpousePolicy x BigCity	0.0689	0.0916*	0.0300	0.119**
	(0.0642)	(0.0524)	(0.0676)	(0.0492)
Constant	1.716***	3.552***	2.532***	3.428***
	(0.238)	(0.217)	(0.253)	(0.249)
Year-Single FE	√	√	√	√
Pref-Single FE	√	√	√	√
Pref Chara.	√	√	√	√
Observations	1,566	1,566	1,564	1,566
R-squared	0.871	0.930	0.885	0.928

The analysis is based on individuals aged 22-35. Single=1 if arriving before marriage. Standard errors clustered at prefecture level are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The sample is restricted to the prefectures with information available.

2.5 Structural estimation

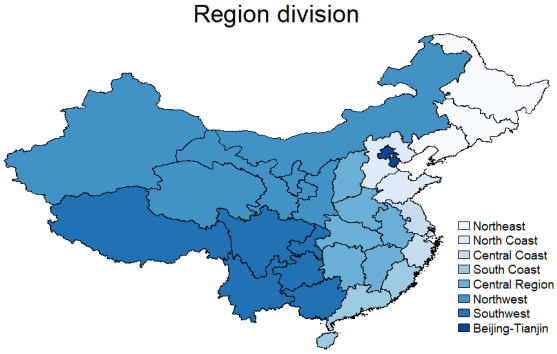
Marriage and migration are interacted decisions. Thus structural estimation helps to disentangle the impact of marriage prospects on migration decisions and the bias of neglecting marriage in the evaluation of migration policies. I estimate the model in section 3 but adopt two adjustments. First, I allow more heterogeneity in locations and individual characteristics. Second, I include additional components that are shown to be important in marriage and migration decisions in the literature such as location-specific amenities. Since China was experiencing large economic changes in the past two decades including the years 2000-2005, the time period of my interest, I allow for time-varying wages and local benefits but do not allow endogenous changes in different migration and marriage equilibriums. A more detailed explanation is as follows.

Note that locals are individuals with local hukou and migrants are those without. Intermarriage refers to the marriage between a local and a migrant, different from the usual definition.

2.5.1 Setup

I divide China into 26 locations according to economic development and geographical location, $d \in \{1,...,26\} \equiv \mathscr{D}$ and divide the 26 locations into eight big regions.[16] The distribution of big regions is in Figure E.4 in which the legend refers to the id of big regions without real meaning. Denote $h \in \mathscr{D}$ as the **place of hukou** registration for each individual. I divide the **education attainment** into three categories: lower than high school education, high school/technical education, or with at least a bachelor's degree, i.e. $e \in \{low, mid, high\}$.

Figure E.4: Big regions



Each woman starts at the age of 20 and exits at the age of 34. Each man starts at the age of 21 and exits at the age of 35.[17] I divide the ages into five-year categories so that each period is five years. The choice of age category, education category, and location division depends on the constraint of dimensionality. Now the dimension of potential cases is $(26 \times 3 \times 3) \times 26 \times (26 \times 3 \times 3 + 1)$.[18] With three categories, I are able to capture the heterogeneity in marriage pressure of different ages. The **age** category $a \in \{1,...,3\} \equiv \mathscr{A}$ increases by one for each period.[19]

In the next period $t+1$, individuals start from the place of hukou registration. This assumption is partly because the state vector only includes hukou place but last location. So migration history

[16] I let each provincial municipality be one location, such as Beijing, Shanghai, Tianjin and Chongqing. In addition, Guangzhou/Shenzhen, the cities at the frontier of international trade and technology development, is also a location. These five locations are important migrant destinations. I divide the rest of China into seven big regions according to geographical location. Beijing and Tianjin belong to another big region, which allows me to capture geographical distance and social distance between the big regions. Within each of the seven big regions, I divide it into three levels (rural, small cities and capitals or economically vibrant cities) to capture the heterogeneity in wage and hukou benefit.

[17] More individuals marry before 35. I use one year difference between men and women because the legal marriage age is 20 for women and 21 for men. Table G.6 in appendix 2.G summarizes the single rate for men and women between 20-35 in years 2000 and 2005. In the case of cohabitation, the participants were considered to be married unless they rejected.

[18] There are $26 \times 3 \times 3$ types of individuals with different places of hukou, ages, and educational attainments. Individuals choose among 26 locations. In each location, the potential spouse types are $26 \times 3 \times 3 + 1$, and the "1" is the choice of staying single.

[19] For examples, for women aged 21-25 ($a = 1$) in 2000, they were aged 26-29 ($a = 2$) in 2005. Each period is five years.

is not taken into account in the future decisions unless it changes individual hukou place or marital status (spouse type). The main reason behind this assumption is to reduce the computation burden of exploded choice set. But this assumption has some cost in a dynamic setup.[20]

2.5.2 Transition of state vector

If the type m man stays single at period t ($\overline{f}=0$), the probability of becoming type m' is

$$\underbrace{TF_t(m',0|m,0,d)}_{\text{for a single type } m \text{ man}} = \underbrace{TF_t(a^{m\prime}|a^m)}_{\text{of age}}\underbrace{TF_t(e^{m\prime}|e^m)}_{\text{of education}}\underbrace{TF_t(h^{m\prime}|h^m)}_{\text{of hukou}}$$

where the hukou transition probability satisfies

$$TF_t(h^{m\prime}|h^m)\begin{cases} 1 & \text{if} \quad h^m = h^{m\prime} = d \\ TF_t^{m0|d} & \text{if} \quad h^{m\prime} = d, h^m \neq d \\ 1 - TF_t^{m0|d} & \text{if} \quad h^{m\prime} = h^m, h^m \neq d \\ 0 & \text{if} \quad \text{otherwise} \end{cases}$$

If the type-m single man chooses a spouse of type f, the transition probability also depends on hukou status or hukou transition of the spouse. If the spouse has local hukou, then the man has an advantage of obtaining local hukou compared to other migrants. If the spouse is also a migrant, the chance of obtaining local hukou by himself is the same as that if he is single. However, he gets local hukou when his migrant wife gets local hukou by herself, because the merit-based hukou reforms usually allow family members to transfer hukou together.

I first predict individual probability of obtaining local hukou based on the regressions explained in the identification and estimation parts. If the destination has lower administrative status than the home location, I replace the predicted probability by zero. For example, individuals with Beijing hukou do not apply for hukou transition in small cities.

2.5.3 Specification of flow utility

In this part, I explain the specifications of deterministic instantaneous utility of the model in section 3. I divide individual utility into two parts: one independent of marriage choices and the other coming from marriage. The flow utility is as follows.

[20] Because of this assumption, the method overestimates the gains from getting local hukou and affects the interpretation of counterfactual. This concern can be mitigated by including a binary state variable indicating whether a person is originally from the place.

- single utility (relevant to all individual regardless of marriage choices)

$$u_t^{m0|d} - c_t^{d|h^m} = \underbrace{s_t^{single}(m,0|d)}_{\text{wage+amenity}} + \underbrace{g_t^{single}(h^m|d)}_{\text{hukou benefit}} - \underbrace{c_t^{d|h^m}}_{\text{mig cost}}$$

$$v_t^{0f|d} - c_t^{d|h^f} = \underbrace{s_t^{single}(0,f|d)}_{\text{wage+amenity}} + \underbrace{g_t^{single}(h^f|d)}_{\text{hukou benefit}} - \underbrace{c_t^{d|h^f}}_{\text{mig cost}}$$

- marital surplus $z_t^{mf|d}$ (the difference of joint utility relative to the sum of single utilities)

$$u_t^{mf|d} + v_t^{mf|d} = u_t^{m0|d} + v_t^{0f|d} + z_t^{mf|d}$$

where $z_t^{mf|d}$ is the marital surplus of a match (m,f).

$$z_t^{mf|d} = \underbrace{s_t^{marry}(m,f|d)}_{\text{wage}} + \underbrace{g_t^{marry}(h^m,h^f|d)}_{\text{hukou benefit}} + \underbrace{marrypref(m,f|d)}_{\text{marriage preference}}$$

where $marrypref(m,f|d)$ is a vector of variables to capture the marriage preferences that cannot be explained by wage, hukou benefit and future utility.[21]

The details of migration cost and marriage preference are in appendix 2.D.

- **single utility from wage and amenity**:

$$s_t^{single}(m,0|d) = \gamma^m \hat{w}_t^{m|d} + (1 + \gamma^{mid}\mathbb{1}_{mid}(e^m) + \gamma^{high}\mathbb{1}_{high}(e^m))\gamma_{dt}$$

$$s_t^{single}(0,f|d) = \gamma^f \hat{w}_t^{f|d} + (1 + \gamma^{mid}\mathbb{1}_{mid}(e^f) + \gamma^{high}\mathbb{1}_{high}(e^f))\gamma_{dt}$$

$$\gamma_{dt} = \gamma_d \times (1 + \gamma^{2005}\mathbb{1}_{2005}(t))$$

where $\hat{w}_t^{m|d}$ is the predicted wage of m men, $\hat{w}_t^{f|d}$ is that of f women in location d at period t. γ_d is the location fixed effect for individuals with less than a high school education and capturing regional amenity. γ^{high} is the relative amenity for the highly educated individuals. γ^{mid} is the relative amenity for individuals with high school/technical education, and γ^{2005} is relative amenity in year 2005 relative to year 2000

[21] In Chiappori, Dias and Meghir (2018), additional marriage preference for spouses with similar levels of education are important to fit the marriage matching pattern in the data. In China, the stigma of marrying a wife with higher education or better social status is important (Ong, Yang and Zhang, 2020).

- **joint marital surplus from wage**

$$s_t^{marry}(m,f|d) = \gamma_t^{mf}(\hat{w}_t^{m|d} + \hat{w}_t^{f|d}) + \gamma^{sup} log(\hat{w}_t^{m|d}) log(\hat{w}_t^{f|d})$$

where $\hat{w}_t^{m|d}$ is the predicted wage of a type-m man and $\hat{w}_t^{f|d}$ is the predicted wage of a type-f woman. γ_t^{mf} captures the difference in marriage rate with the increase of wage at year t, and γ^{sup} captures the degree of supermodularity of utility from consumption. $K_t^{marry}(m,f|d)$ is the household marital surplus related to wage.

- **single utility from hukou benefit**:

$$g_t^{single}(h^m|d) = \delta_t^d \mathbb{1}_d(h^m)$$

$$g_t^{single}(h^f|d) = \delta_t^d \mathbb{1}_d(h^f)$$

$$\delta_t^d = \delta_d \times (1 + \delta^{2005} \mathbb{1}_{2005}(t))$$

where δ_d is the location-specific hukou benefit in 2000, δ^{2005} measures the relative benefit in year 2005, and $\mathbb{1}_d(h^m)$ is dummy of whether the place of hukou registration h^m is the place of residence d.

- **marital surplus from the benefit extension to spouse**

$$\begin{aligned} g_t^{marry}(h^m,h^f|d) =& (b^m + b^p SPolicy_t^d)\delta_d \mathbb{1}_{urban}(h^m) \underbrace{\mathbb{1}_d(h^m)(1-\mathbb{1}_d(h^f))}_{\text{local men with temporary migrant women}} \\ &+ (b^f + b^p SPolicy_t^d)\delta_d \mathbb{1}_{urban}(h^f) \underbrace{\mathbb{1}_d(h^f)(1-\mathbb{1}_d(h^m))}_{\text{temporary migrant men with local women}} \end{aligned}$$

where $SPolicy_t^d$ is local-spouse-based hukou reforms in location d in year t. b^m captures the direct benefit to the temporary migrant women if the husbands have local hukou. b^f is the direct benefit to the migrant men if the wives have local hukou, and b^p captures the change in the benefit associated with spouse-based hukou policies. In addition to the direct benefit, spouse-based reforms also affect spouse hukou transition. I only allow this intermarriage benefit in cities, because the benefit of rural hukou mainly comes from the land and land allocation was mostly settled in 1998.

2.5.4 Equilibrium

I focus on Nash equilibrium where 1) individuals cannot foresee future changes in wages, hukou benefit and migration policy, i.e.$E_\xi U_{t+1}(m', \overline{f}', \varepsilon_{i,t+1}) = E_\xi U_t(m', \overline{f}', \varepsilon_{i,t+1})$, and 2) unob-

served marriage preference in location d is independent of location preference, i.e. $\varepsilon^{\bar{f}|dit} \perp \varepsilon^{d}_{it}$. The first assumption implies that individuals do not have perfect foresight and forecast based on the elder's experience. The second assumption implies that individuals with an idiosyncratic taste for well-educated spouses do not cluster in big cities after controlling for the observed variables.

2.5.5 Identification

To run counterfactuals, I need to obtain the individual predicted wage in each location, the flow utility for a given choice at period t, and the probability of hukou transition. This section discusses the identification.

Wage Equation

To obtain the predicted wage for each individual, I need to estimate the wage equation for each location d. The predicted wage in location d is the same for individuals with the same individual characteristics.

I do not model the idiosyncratic realization of wages in the structural model after controlling all the observable characteristics. But in the estimation of wage equations, I want to mitigate the bias from the following selection problem: the wage is only observable at the chosen location, and individuals may migrate when they expect higher wages. In addition to the variables usually used to estimate wage equation, migration cost and marital status also influence individual migration decisions. Here, I deal with the selection problem by using variables related to migration cost and marital status to construct a control function.[22] I apply the method of Lee (1983) which only requires the estimation of one parameter in the correction term:

$$\begin{aligned} log(w_{id}) =& \alpha_{0d} + \alpha_{1d} Eduy_i + \alpha_{2d} Age_i + \alpha_{3d} Age_i^2 + \alpha_{4d} Female_i + \alpha_{5d} FEduy_i + \alpha_{6d} RuralHukou_i \\ &+ \alpha_{7d} Migrant_{di} + \alpha_{8d} MigrantRural_{di} + \sigma_d \phi(\Phi^{-1}(\hat{p}_d(x_i)))/\hat{p}_d(x_i) + \iota_i \end{aligned}$$

where $\hat{p}_d(x_i)$ is the predicted probability of choosing location d from a multi-nominal logit regression of location choice over the relevant variables described below. $Eduy_i$ is the year of

[22] The selection problem can be characterized as follows:

$$w_1 = X\eta_1 + \mu_1$$

$$y_j* = Z\nu_j + \zeta_j$$

where w_1 is the vector of wages of individuals choosing location 1, X is the explanatory variables of wage equations, and Z is the matrix of variables relevant for location choices. y_j* is a latent variable. Individuals choose location 1 only when y_1* is the largest among all the choices, i.e. $y_1* > \max_{j\neq 1} y_j*$. The literature proposes several ways to correct for the bias due to the correlation between μ_1 and ζ_j, with different assumptions of the joint distribution.

education. Age_i is the age. $Female_i$ is female dummy. $FEduy_i$ in the interaction between female dummy and education. $RuralHukou_i$ is the dummy of having rural hukou. $Migrant_{di}$ is the dummy of being a migrant, and $MigrantRural_{di}$ is the dummy of being a migrant with rural hukou.

$$\begin{aligned} Location_i =& a_{0d} + a_{1d}Eduy_i + a_{2d}Age_i + a_{3d}Age_i^2 + a_{4d}Female_i + a_{5d}FEduy_i + a_{6d}RuralHukou_i \\ &+ a_{7d}Migrant_{di} + a_{8d}MigrantRural_{di} + a_{9d}DifBigRegion_{di} + a_{10d}DifLocType_{di} \\ &+ a_{11d}Distance_{di} + a_{12d}DifLocType_{di} \times Distance_{di} + a_{13d}Single_{di} + \varepsilon_{id} \end{aligned}$$

where $Location_i$ is the location chosen by individual i. $DifBigRegion_{di}$ is the dummy of leaving the big region of home. $DifLocType_{di}$ is the dummy of migrating from rural to urban areas or the other way around. $Distance_{di}$ is the distance between destination and home, and $Single_{di}$ is a dummy of being single.

Hukou transition probability

I need to predict the hukou transition probability within five years after migration. The probability depends on merit-based and spouse-based hukou reforms and individual characteristics. The relevant data come from the migration history backed out from the 2012-2016 CLDS data. The variations in hukou reforms over time and across prefectures help me to identify the impact of hukou reforms on hukou transition.

I run two regressions to separately analyze 1) the probability that migrants obtain hukou at the first year of migration and 2) the probability that migrants obtain hukou within five years of migration conditional on not obtaining it in the first year.[23] The first regression regresses whether migrant i obtains local hukou at the first year of migration over migrants' individual characteristics, regional migration policies, and some regional characteristics using logit regression. The second examines whether migrant i obtains local hukou within five years of migration given they did not obtain it in the first year. The final predicted probability of obtaining local hukou within five years is equal to the probability of transfer in the first year plus the probability after 2-5 years given not obtaining hukou earlier, i.e. $TF_{1-5} = TF_1 + (1 -$

[23] There are four considerations in the estimation of hukou transition. First, there is yearly variation in migration policy, individual education level, and spouse hukou. Collapsing it into one observation for each individual for the whole lifetime might eliminate crucial variations. Second, individuals can obtain local hukou at year t conditional on not obtaining hukou before. The relaxation of migration policy at period t not only increases the chance that migrants obtain hukou at period t but also negatively affects the observed chance that the left migrants obtain hukou at $t+1$ under the same policy. Third, hukou reforms increase the number of migrants. If the average skill level of migrants decreases, then the impact of hukou reforms on migrants' probability of obtaining local hukou may be underestimated. Fourth, the degree of policy relaxation is not random and likely to be correlated with economic development and resource availability.

$TF_1) \times TF_{2-5}$.

The detailed specification is as follows:

$$\begin{aligned} ObtainHukou_{idt} = {} & \alpha_0 + \alpha_1 Female_i + \alpha_2 Rural_d + \alpha_3 RuralHukou_{it} + \alpha_4 MeritPolicy_{dt} \\ & + \alpha_5 RuralHukou_{it} \times MeritPolicy_{dt} + \alpha_6 \mathbb{1}_2(Edu_{it}) + \alpha_7 \mathbb{1}_3(Edu_{it}) \\ & + \alpha_8 \mathbb{1}_2(Edu_{it}) \times MeritPolicy_{dt} + \alpha_9 \mathbb{1}_3(Edu_{it}) \times MeritPolicy_{dt} \\ & + \alpha_{10} SpousePolicy_{dt} + \alpha_{11} LocalSpouse_{it} \times SpousePolicy_{dt} + \iota_p + \iota_t + X_{dt}\beta + \varepsilon_{idt} \end{aligned}$$

where each observation is a migrant i in location d in year t. $ObtainHukou_{idt}$ is a dummy of whether migrant i obtains hukou at destination d. t in column (1) is the first year of migration, and t in column (2) is the second year of migration. $Female_i$ is the female dummy. $Rural_d$ is the dummy of whether d is a rural area. $RuralHukou_{it}$ is the dummy of whether the migrant i has rural hukou before migration. $MeritPolicy_{dt}$ in column (1) is the general hukou reform index belonging to $\{0,1,2,3\}$ in the first year of migration. $MeritPolicy_{dt}$ in column (2) is the average reform index of 2nd-5th year of migration. $\mathbb{1}_2(Edu_{it})$ is the dummy of whether migrant i has high school or technical education at year t. $\mathbb{1}_3(Edu_{it})$ is the dummy of whether migrant i has at least bachelor education at year t. The interactions between education dummies and hukou reforms measures the partiality of reforms. $SpousePolicy_{dt}$ is the hukou policies on spouses of local citizens and the difference between two regressions is the same as $MeritPolicy_{dt}$. ι_p and ι_t are province FE and year FE. X_{dt} is the regional characteristics to control the selection of hukou policies and migrants, including the log of distance to port, urbanization rate, population density, the log of GDP per capita, and log of the number of migrants.

Parameters of utility components

In this part, I briefly discuss about the identification of parameters entering flow utility. Additional details are in appendix 2.E.

To identify the parameters of the flow utility, I need to fix the discount factor β, normalizing the utility of one option, make an assumption on the distribution of taste shocks, and obtain the state transitions (Magnac and Thesmar, 2002). Assume $\beta = 0.77 = 0.95^5$, because each period in the model is five years. Normalize the fixed amenity in the first location to be zero.[24] The taste shocks satisfy extreme value type I distribution. The transition matrix of state vector is determined by the hukou transition (section 5.6.2) and the transition of age. Education remains fixed for each individual.

Applying the inversion theorem in Hotz and Miller (1993), the continuation value can be

[24] Normalize the utility of a single migrant with zero wage and age category $a = 3$ in the first location to be zero, which does not include the migration cost

written as a function of flow utility and conditional choice probabilities (CCPs). Given that the taste shocks satisfying extreme value type I distribution, the continuation value is given by:

$$\beta \sum_{m'} \sum_{f'} TF_t(m', f'|m, f, d) E[U_{t+1}(m', f') + V_{t+1}(m', f')]$$

$$E[U_{t+1}(m', f') + V_{t+1}(m', f')] = U^{m',f'}_{h_{m'},t} + V^{m',f'}_{h_{m'},t} - log(\frac{p_t(f', h_{m'}|m')}{\sum_d p_t(f', d|m')})$$

where $U^{m',f'}_{h_{m'},t} + V^{m',f'}_{h_{m'},t}$ is the joint household utility at the home location of the husband, and $\frac{p_t(f', h_{m'}|m')}{\sum_d p_t(f', d|m')}$ is the observed probability of choosing to stay at the home location of the husband given the wife is of type f'. If one partner exits next period and the other one remains in the model, the future expected utility is computed using the single utility without the options of re-entering the marriage market.

The parameters of flow utility can be divided into four types: 1) relevant to all individuals, such as amenity and wage $s^{single}_t(\cdot|d)$, 2) specific to locals, such as hukou benefits $g^{single}_t(\cdot|d)$, 3) specific to migrants, such as migration costs $c^{d|h_m}_t$ and $c^{d|h_f}_t$, and 4) specific to couples, such as marital surplus $z^{mf|d}_t$. The former three types can be identified by the location choice probabilities of individuals remaining single at time t, while the last type can be identified by the probabilities of individuals entering marriage.

I start with the identification of the single utility. To show the intuition, I first focus on the individuals at the termination period, i.e. $a = 3$, and then discuss how the variations in hukou reforms contribute to the identification of hukou benefits. For example, pick one type of individuals from location A, the difference in choice probability of migrating to location d and d' depends on the difference in migration costs, amenities, and predicted wages.

$$log(\frac{p_t(0, d|m)}{p_t(0, d'|m)}) = u^{m0|d}_t - u^{m0|d'}_t - c^{d|h^m}_t + c^{d'|h^m}_t = [K^{single}_t(m, 0|d) - K^{single}_t(m, 0|d')] - (c^{d|h^m}_t - c^{d'|h^m}_t) \tag{2.4}$$

By picking another type of individuals from location B but who share the same age, education, and hukou status (rural/urban), I can cancel out the amenities and predicted wages that are the same for both types of individuals. This allows me to identify the parameters of migration cost except for the constant cost that every migrant pays. The wage parameters γ^m and γ^f can be further identified if I change hukou status of the individuals, because hukou status affects wage but not the access to amenities.

After controlling migration costs and wages, I can identify the difference in amenities across location and other parameters related to amenities that are the only components left unidentified in the variations in equation (2.4).

After comparing the destination choice probabilities of migrants, I now use the variations in the probabilities of migrating to a new location relative to the probabilities of staying at the home location to jointly identify the constant migration cost and the hukou benefits $\delta_t^{h^m} + c^0$. The difference in hukou benefits can be identified from two sources: 1) the variation in out-migration rate across regions, and 2) migrant responses to hukou reforms across destinations and over time. From the destination choice probabilities of migrants of young cohorts, hukou reforms enter the expected utility through hukou transition. For example, the variations in destination choices over time give me the variations in expected gains of hukou benefits:

$$TF_t(m',0|m,0,d)(\delta_{d,t} - \delta_{h^m,t}) - TF_{t+1}(m',0|m,0,d)(\delta_{t+1}^d - \delta_{t+1}^{h^m})$$

where TF_t is the probability of obtaining local hukou of location d for type m men staying single. $\delta_t^d - \delta_t^{h^m}$ is the gains of hukou benefits if transfering the hukou from location h^m to d.

To identify the levels of hukou benefits, I exploit the policy of land allocation in China. In 1998, there was a nationwide allocation of land based on household composition in rural areas. Few changes were made afterwards even if household composition changed. Thus I assume the benefit extension to intermarriage in rural areas is zero.

The last part is the identification of the marital surplus. With the relative choice probabilities of marriage compared to staying single for both men and women, I can identify the joint surplus:

$$log(\frac{p_t(f,d|m)}{p_t(0,d|m)}) + log(\frac{q_t(m,d|f)}{q_t(0,d|f)}) = Z_t^{mf|d}$$

By comparing the probability of choosing local spouses in different locations relative to other migrants, I identify the parameters of benefit extension in local/migrant marriages.

2.6 Results of structural estimation

The section entails three parts: the estimation of wages in each location, migrant hukou transition probabilities, and the parameters in the utility specification.

2.6.1 Wage

I estimate the wage equations separately for the 26 locations and predict the wage for each individual in each of the 26 locations. The predicted wages for a given location are the same among individuals with the same characteristics. I only have monthly wage information in Census 2005, based on which I predict the wages in year 2005 and then adjust the wages in 2000 and 2005 using CPI and regional growth of GDP per capita. The top 1% and the bottom 1% of

actual wages in each location are excluded to avoid extreme wages. The number of observations, summary statistics of wage, estimates of the explanatory variables and predicted wages by gender in 2005 are summarized in Appendix 2.F. The mean wage is the average wage of those observed in location d by gender, while the predicted wage is the average wage of the whole sample. The difference in sample explains why the predicted wage is different from the actual mean wage. Overall, the predicted wage is higher than the actual mean wage in rural areas but lower than in cities.

To approximate the predicted average wage in 2000, I use the regional GDPPC in 1998-2005 to obtain the average GDPPC for years 1998-2000 and 2001-2005. The details of the ratio are in Appendix 2.F. To obtain the predicted wage in 2000, I multiply the predicted wage from census 2005 and the ratio for each location. In addition, I adjust the rural and urban wage using provincial CPI from China Compendium of Statistics 1949-2008 and CPI in 2000 from Brandt and Holz (2006).

2.6.2 Migrant hukou transition probability

The goal is to predict the migrant hukou transition probability in a given location and for a given individual five years after migration. The data contains annual information on individual places of residence and registration (hukou), marital status and individual characteristics since birth.

The results are in Table F.6. In the regression, I keep all observations of migrants aged 18-55 until the year they obtain hukou. In addition, I focus on the cases where individuals obtained local Hukou not due to studying, military service, transfer of military cadres to civilian work, sent-down, and providing support to remote areas. I assume individuals only apply for local hukou if the location has the same or a better status than the source location. I divide prefectures into three status categories: 1) small prefectures, 2) capitals and some big cities, and 3) mega cities.

The 2,187 observations each represents the experience of a migrant i in destination d. The interpretation of the coefficients related to HukouReform measuring the relaxation of general policies (attracting skilled labor and investment and independent of spouse's hukou) is as follows: the reform significantly increases the probability that migrants with rural hukou obtain hukou at destinations in the first year, but has a positive but insignificant additional impact on those migrants with at least high school education. The coefficients related to spouse policies imply that the relaxation of criteria on migrant spouses of locals increases their probability of obtaining local hukou. The general hukou reforms are expected to decrease the value of intermarriage with locals, while the reforms contingent on being spouses of locals are expected to increase that value.

Table F.6: Determinants of migrant hukou transition probability (Logit)

VARIABLES	(1) HukouChange 1yr	(2) HukouChange $2-5$yr
Female	0.988***	1.235***
	(0.144)	(0.302)
Rural(destination)	3.898***	4.348**
	(0.929)	(2.030)
RuralHukou	-2.715***	-0.769
	(0.301)	(0.624)
MeritPolicy	-0.305	0.214
	(0.227)	(0.529)
RuralHukou x MeritPolicy	0.505**	-0.166
	(0.217)	(0.528)
High school/Technical edu.	0.0444	1.058*
	(0.283)	(0.583)
$\geq$Bachelor	0.256	2.085*
	(0.548)	(1.206)
High school/Technical edu. x MeritPolicy	0.233	-0.660
	(0.204)	(0.473)
$\geq$ **Bachelor x MeritPolicy**	0.385	-1.026
	(0.343)	(0.899)
SpousePolicy	-0.195**	-0.201
	(0.0850)	(0.196)
LocalSpouse x SpousePolicy	0.399***	0.273
	(0.0951)	(0.198)
Constant	-2.701	-14.53**
	(1.759)	(6.890)
Year FE	Y	Y
Province FE	Y	Y
Observations	2,187	1,619

Each observation is an individual. Year FE and province FE are controlled. Regional characteristics such as log of GDP per capita, log population, teacher to student ratio, log of distance to port, and log of number of migrants are controlled. The first estimation is a logit regression of whether individual i obtains local hukou at the first year of migration. The second estimation is a logit regression of whether individual i obtains local obtain at the 2-5 years of migration. The two regressions are used to predict individual probability of obtaining local hukou within fives years after migration. Standard errors clustered at county level are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The prediction from the two logit regressions leads to the predicted probability that a migrant i obtains hukou at destination d five years after migrating in the year t. The prediction is at prefecture and rural/urban level, and I further aggregate the probability at the 26-location level weighted by the number of migrants by prefecture and rural/urban level for individuals with different gender, education, hukou status and spouse type. The average of the hukou transition probability is 0.150 in 2000, 0.169 in 2005, and 0.208 in 2010, taking into account that the probability is one for locals and zero if migrants are in locations categorized lower than their hukou places.

2.6.3 Parameters of utility function

This section focuses on the parameters of the flow utility. The estimation procedure is in appendix 2.A. It entails the estimates of regional utility of singles, the relative utility brought by marriage, the size of hukou benefit, and the size of benefit extension to spouses.

The estimates of utility parameters are summarized in Table F.7. The parameter of wages (1000 CNY) in the single utility is 0.62 for men and 0.90 for women. This difference between genders is mainly driven by the gender wage gap. Women's wages were on average two-thirds of those of men. Given that the wage is in unit and in CNY, the shadow price can be easily computed with the coefficients. The shadow price of hukou benefits is \$87 for men and \$61 for women in 2005. [25]

$b_m = 0.82$ and $b_f = 0.87$ are the share of local hukou benefits that female and male migrants get from intermarriage with locals. Their magnitudes imply that the privileges from intermarriage with locals are large. $b_{pm} = 0.22$ and $b_{pf} = 0.49$ indicate that spouse-based hukou reforms increase the benefit extension that migrants get through intermarriage with locals.

Table F.7: Parameters of flow utility-part

Variables	Coefficient	SE
Single utility		
Wage of men (1,000 CNY) γ^m	0.63	0.01
Wage of women (1,000 CNY) γ^f	0.91	0.01
Relative amenity of the highly educated vs. those with less than a high school education γ^{high}	-0.62	0.01
Relative amenity if with high school/technical education γ^{middle}	-0.38	0.003
Relative amenity of year 2005 γ^{2005}	1.30	0.01
Relative benefit of year 2005 δ^{2005}	0.80	0.01
Average hukou benefit in rural areas	-1.18	
Average hukou benefit in small cities	-0.04	
Average hukou benefit in big cities	0.71	
Average hukou benefit in mega cities	0.84	
Marital surplus		
joint wage (1000 CNY) of year 2000 γ^{mf}_{2000}	-0.51	0.02
joint wage (1000 CNY) of year 2005 γ^{mf}_{2005}	-0.25	0.02
multiplication of log of wage γ^{sup}	0.03	0.001
Ratio of benefit of marrying locals for female migrants b_m	0.82	0.02
Ratio of benefit of marrying locals for male migrants b_f	0.87	0.04
Relative benefit of marrying locals for female migrants due to spouse policies b_{pm}	0.22	0.01
Relative benefit of marrying locals for male migrants due to spouse policies b_{pf}	0.49	0.02

The coefficients and standard errors are rounded to two decimal places. The standard errors are computed from the hessian matrix without the correction for the first stage estimations of wage and state transitions.

[25] The population weighted hukou benefits in large cities is 0.57. Thus, the shadow price of hukou benefits in CNY is 724 CNY per month for men and 501 CNY for women, which are \$87 for men and \$61 for women in 2005 if I apply the exchange rate that one dollar equals to 8.28 CNY. The average monthly wage after adjusting the CPI is 1,247 for men and 1,053 for women in 2005. Thus, hukou benefits are equivalent to 58% of monthly wages for men and 48% for women.

2.6.4 Fit of model

In this subsection, I examine the fit of the model by comparing the out-migration rate, location choice, marriage rate, and intermarriage rate with locals in the data and predicted by the estimates of the model. The results are summarized in appendix 2.I. The overall fit is good with a small under-prediction of migrants in large cities and an over-prediction of the intermarriage rate.

2.7 Counterfactuals

I answer the two research questions using counterfactual simulations. First, how much do marriage prospects contribute to the migration to large cities in China? Second, to what extent do marriage adjustments affect the migration to large cities if migrants can obtain local hukou immediately after migration? For the second question, I analyze the case where all migrants obtaining local hukou immediately and that where only highly educated ones obtaining immediately.

2.7.1 Impact of marriage prospects on migration

Marriage prospects include the opportunities of finding spouses outside home and the indirect gains of own migration success in the marriage market. To quantify the effect of marriage prospects on migrant flows, I first shut down the marriages between couples with different hukou places. The number of migrants aged 20-35 in large cities decreases by 5.6% in 2000 for men and 12.8% for women. Then I decompose the effect of privileges that migrants get in local/migrant marriages, by assuming migrants get zero hukou benefits and no advantage in hukou transition in local/migrant marriages. The number of migrants decreases by 1.9% for men in 2000 and 3.5% for women. Table G.8 shows the effect of marriage prospects on the number of migrants in large cities by gender, education, and year. The effect of marriage prospects decreases from 2000 to 2005. In terms of gender, marriages outside hukou places are more important for women than for men. In 2000, 10.5%, 13.3%, and 12.56% of female migration to large cities for those with a high, middle, or low level of education.[26] The corresponding percentage changes for men are 7.7%, 6.4%, and 5.0%. Note that the opportunities of marrying up were negligible for men according to (Dupuy, 2021). This difference originates from the difference between dynamic and static model. Here the expected marital gains by migration are not only from the opportunities of marrying natives, but also from the marital gains from being more attractive after getting local hukou. Indeed the effect is greater for male migrants with a higher level of education.

[26] The problem of sex ratio imbalance in China has negligible effect for the cohort in this paper. In the 2005 census, the size of male newborns began to exceed that of female newborns after 1988.

Table G.8: Effect on the number of migrants aged 20-35 in large cities

	2000		2005	
	M	F	M	F
	$\geq$ College			
Marriages between couples with different hukou places	7.71%	10.54%	3.61%	4.38%
Benefits from local/migrant marriage	3.13%	3.39%	0.95%	0.85%
	High school/technical education			
Marriages between couples with different hukou places	6.39%	13.30%	3.78%	7.42%
Benefits from local/migrant marriage	2.47%	4.08%	0.90%	1.68%
	$\leq$ Middle school education			
Marriages between couples with different hukou places	4.98%	12.56%	3.69%	6.51%
Benefits from local/migrant marriage	1.53%	3.20%	0.71%	1.32%

2.7.2 Granting migrants immediate access to local hukou and locals' benefits (similar to open border policy)

Whether to eliminate hukou privileges and grant migrant access to local public services in China is a crucial topic. This is similar to open border policies in international migration in the sense that any migrant has the same access to benefits as locals. Here I simulate the out-migration rate from the rural areas and small cities to big/mega cities if the hukou benefits are open to all migrants. Table G.9 provides out-migration rates of the population in rural areas and small cities to large cities. After eliminating the hukou system, locals are less attractive for migrants in the marriage market and have smaller bargaining power in the marriages with migrants. Similarly, highly educated migrants are less attractive for the other migrants in the marriage market and have- smaller bargaining power in these matches. The migrant flows to big/mega cities increase significantly, especially for low educated migrants. The number of migrants in large cities increases by 3.1 times for men and 2.7 times for women. The change in migrant flows is more substantial in 2000 than in 2005 because hukou reforms were less advanced in 2000. In addition, the predicted share of locals marrying temporary migrants increases by from 7.5% to 14.4% in 2000 and from 6.8% to 9.9% in 2005. The variation in the intermarriage rate by region is summarized in Table G.10.

To show the importance of embedding marriage choices in the evaluation and design of migration policies, I study the counterfactual scenario of removing hukou restrictions without marriage market adjustments. Marriage adjustments refer to the changes of utility division (bargaining power) within households and the changes in spouse choices (ex-ante probability of spouse choice before the realization of idiosyncratic spouse preference). Without marriage market adjustments, the number of migrants in large cities increases by 2.2 times for men and 1.6 times for women, much smaller than the increase allowing for marriage market adjustments.

Looking at the heterogeneity by demographics, it is easy to observe that including marriage adjustments reduces the positive policy impact on the number of highly educated migrants while increases the positive impact on that of migrants with less than high school education.

Table G.9: Relative number of migrants migrating to large cities ($\frac{x_{new}}{x_{old}}$) after removing hukou restrictions

Type	M-2000	F-2000	M-2005	F-2005
	With marriage adjustments			
$\geq$ College	0.07	0.11	0.45	0.36
High School/Technical Education	0.85	0.61	1.14	0.85
$\leq$ Middle School	2.99	2.46	3.47	3.02
	Without marriage adjustments			
$\geq$ College	0.34	0.20	0.47	0.14
High School/Technical Education	0.37	0.21	0.27	0.08
$\leq$ Middle School	1.68	0.78	0.69	0.32

Table G.10: Intermarriage rate of permanent residents in 2000

Category	Baseline	Removing restriction	Full access to benefits
Rural	4.18%	4.76%	2.26%
Small cities	10.35%	19.13%	9.55%
Medium cities	19.48%	27.23%	16.95%
Big cities	19.45%	36.89%	18.68%

The above changes are driven by two forces. First is the immediate access to local hukou benefits. Second is the increased transition probability of becoming a local and higher future expected utility associated with being a local in large cities. If the second channel is shut down, the predicted share of locals marrying temporary migrants decreases by from 7.5% to 6.0% in 2000 and from 6.8% to 5.5% in 2005. The number of migrants into large cities increases by 0.72 times for men and 0.65 times for women. Without the change in the utility division within couples, the numbers become 0.74 times for men and 0.65 times for women.

2.7.3 Removing hukou restriction only for the highly educated migrants

Here I analyze the counterfactual policy of only granting migrants with at least a bachelor's degree the immediate access to local status and local benefits. Given that the highly educated migrants constitute only a small portion of the whole population, to better present the change in average skill level, I use the change in total population and population share by education level in Table G.11.[27] The results of 2000 show that neglecting marriage market adjustments,

[27] In the theoretical analysis, I examine the change in average migrant skill level because only migration from the sending region to the receiving region is allowed. Here the more direct measure is the composition of the whole population, including the natives and migrants.

we would underestimate the increase of total population and overestimate the share of highly educated population.

Table G.11: Population structure after removing hukou restrictions on the highly educated in 2000

Type	Population $\frac{x_n^{ew}}{x_o^{ld}}$	% of HighEdu	% of MidEdu	% of LowEdu
with marriage adjustments	1.011	8.47%	45.74%	45.79%
without marriage adjustments	1.001	8.77%	47.55%	43.68%

2.8 Conclusion

In this paper, I analyze how the negligence of marriage adjustments shapes the impact of merit-based migration policies on migrant flows. I also quantify the importance of marriage prospects in the internal migration of the cohort aged 20-35 in China. To the best of my knowledge, it is the first study to investigate the impact of merit-based migration policies on migrant flows taking into account the indirect policy effect through marriage prospects and quantify the total impact of hukou elimination considering this indirect effect. This paper also contributes to the literature by decomposing the benefit of intermarriage with locals in the internal migration in China, taking into account the marital gains from obtaining local status.

The theoretical analysis studies the comparative statics of migrant flows with respect to the migration policy favoring high-skilled migrants. When high-skilled migrants have higher chances of obtaining local status, the number of low-skilled migrants also increases, because low-skilled migrants can enjoy local benefits by marrying high-skilled spouses who pass the policy restrictions. Neglecting the indirect policy effects through marriage markets, we underestimate the increase of migrants when migration policy relaxes, and underestimate its decrease when migration policy become more stringent.

In China, there have been discussions on whether to remove hukou restrictions and open hukou benefits to migrants. I analyze the migrant flows to large cities after hukou eliminiation and contribute to the discussion by considering the indirect impact on marriage prospects. The increase in the number of migrants is substantial, 3.1 times for men and 2.7 times for women. Those increases are mainly driven by migrants with a lower than high school education. Neglecting the indirect effect through marriage markets, we would underestimate the migration of men by about 30% and of women by 40%. Furthermore, we would underestimate the number of low-skill migrants in large cities and overestimate the number of high-skill migrants.

The insights that marriage prospects are important for migration and regulation can be extended to immigration policies, such as European border control in the Mediterranean Sea and the US-Mexico border. It is vital to embed marriage adjustments in the evaluation and design of

migration policies. Though Brexit is more than a regulation on free movement between the UK and the EU, marriage prospects are also important to predict the migration from the EU or other countries to the UK. Nowadays there is increasing political attention on marriage migration in many countries such as Denmark, Netherlands, and the UK. These countries use minimum age, minimum wage, and language requirements to control the migrants through marriage, creating family separation problems. Embedding marriage migration in the design of general migration policies might mitigate the demand for marriage intervention. How to design migration policies to balance social problems and economic growth demands further investigation.

This study has several limitations. First, the current sample is made up of people who were aged 20-35 and single five years ago. In the future, I can relax this assumption and extend the study to all individuals aged 20-55. Second, I only use the population censuses from 2000 and 2005, and I could include more variation by adding the 2010 census. Third, I do not allow for labor market adjustment. The ultimate change in migration flows varies with the determination of production function. If congestion brings disutility, I over-predict migrant flows. If there is a positive knowledge spillover or agglomeration effect, I under-predict the migrant number.

Appendix 2.A Solving for marriage market equilibrium

The inner-loop of marriage market equilibrium is based on Dupuy (2021). The marriage matching pattern given migration decisions can be uniquely determined given the initial population of singles by type and the value of integrated deterministic component of marital surplus $Z_t^{mf|d}$. Note that the uniqueness of marriage matching equilibrium relies on the assumption that each marriage market is large enough, which may not be valid here.

Specifically, denote $n_t^{mf|d}$ as the number of newly formed (m, f) couples in location d, $n_t^{m0|d}$ as the number of m men choosing location d, and $n_t^{0f|d}$ as that of f women choosing location d. We have

$$\sum_{f \in \mathscr{F}_d} n_t^{mf|d} + n_t^{m0|d} = N_t^{m|d}$$

$$\sum_{m \in \mathscr{M}_d} n_t^{mf|d} + n_t^{0f|d} = N_t^{f|d}$$

where $N_t^{m|d}$ is the number of single m men at period t in region d and $N_t^{f|d}$ is that of single f women.

The marriage matching equilibrium $n_t^{m0|d}$ and $n_t^{0f|d}$ can be pinned down by the marriage market clearing conditions:

$$n_t^{m0|d} = (\sqrt{N_t^{m|d} + (\frac{\sum^f K_d^{mf} \sqrt{n_t^{0f|d}}}{2})^2} - \frac{\sum^f K_d^{mf} \sqrt{n_t^{0f|d}}}{2})^2$$

$$n_t^{0f|d} = (\sqrt{N_t^{f|d} + (\frac{\sum_m K_d^{mf} \sqrt{n_t^{m0|d}}}{2})^2} - \frac{\sum_m K_d^{mf} \sqrt{n_t^{m0|d}}}{2})^2$$

where $K_d^{mf} = exp(\frac{Z_t^{mf|d}}{2})$.

Appendix 2.B Comparative statics of marriage rate and matching pattern

The comparative statics of marriage rate and matching pattern are in Figure B.1 and Figure B.2. The marriage rate corresponds to the share of singles entering marriage in region r in each period t. In other words, those who change local status after marriage are not taken into account. When p_h increases, high-skilled migrants postpone their marriage waiting for realization of local status, while high-skilled locals as close substitutes tend to marry earlier to escape competition in the future.

The degree of assortative marriage matching is calculated using new marriages in each period t. Couples enjoy extended local benefits only in intermarriages, marriages between those with local status and those without. When p_h increases, the degree of assortative matching on education in region r decreases because the gains of intermarriage between high-skilled migrants and high-skilled locals is moderate compared to marriage between high-skilled and low-skilled migrants. The degree of assortative matching on local status in region r the gains of intermarriage decrease.

Appendix 2.C The proof of equilibrium existence in the dynamic structural model

The idea is as follows. The dynamic migration equilibrium of the singles at period t can be transformed into a fixed-point problem, which is characterized by the location choice probabilities (LCP) of singles by type.[28] To prove the equilibrium existence, I use Brouwer's fixed point theorem. This theorem requires the LCPs to a nonempty, closed, bounded and convex set and the mapping function to be continuous on the set of LCPs. However, since idiosyncratic location preference satisfies Gumbel distribution, any of the LCPs belongs to the open set $(0,1)$. To apply the Brouwer's fixed point theorem, I extend the mapping function to the 0/1 boundaries, make it continuous as LCPs approach the boundary, and then show that the equilibrium does not exist on the boundary.

Denote $p_t = \{p_t^1, ...p_t^m, ..., p_t^{\dim(\mathscr{M})}\}$ as the vector of location choice probabilities of men by type (individual characteristics) and $q_t = \{q_t^1, ..., q_t^f ..., q_t^{\dim(\mathscr{F})}\}$ as that of women by type, where $p_t^m = \{p_t^{m|1}, ..., p_t^{m|D^m}\}^T, m \in \{1, ..., \dim(\mathscr{M})\}, \sum_{1 \le d \le D^m} p_t^{m|d} = 1$ is the vector of choice probabilities that type m men choose location d and $q_t^f = \{q_t^{f|1}, ..., q_t^{f|D^f}\}^T, f \in \{1, ..., \dim(\mathscr{F})\}$, $\sum_{1 \le d \le D^f} q_t^{f|d} = 1$ is that of type f women. Denote Ψ as the mapping function characterizing the

[28] The LCPs of married ones will not influence the singles since I abstract from labor market adjustments.

Figure B.1: Comparative statics of marriage rate

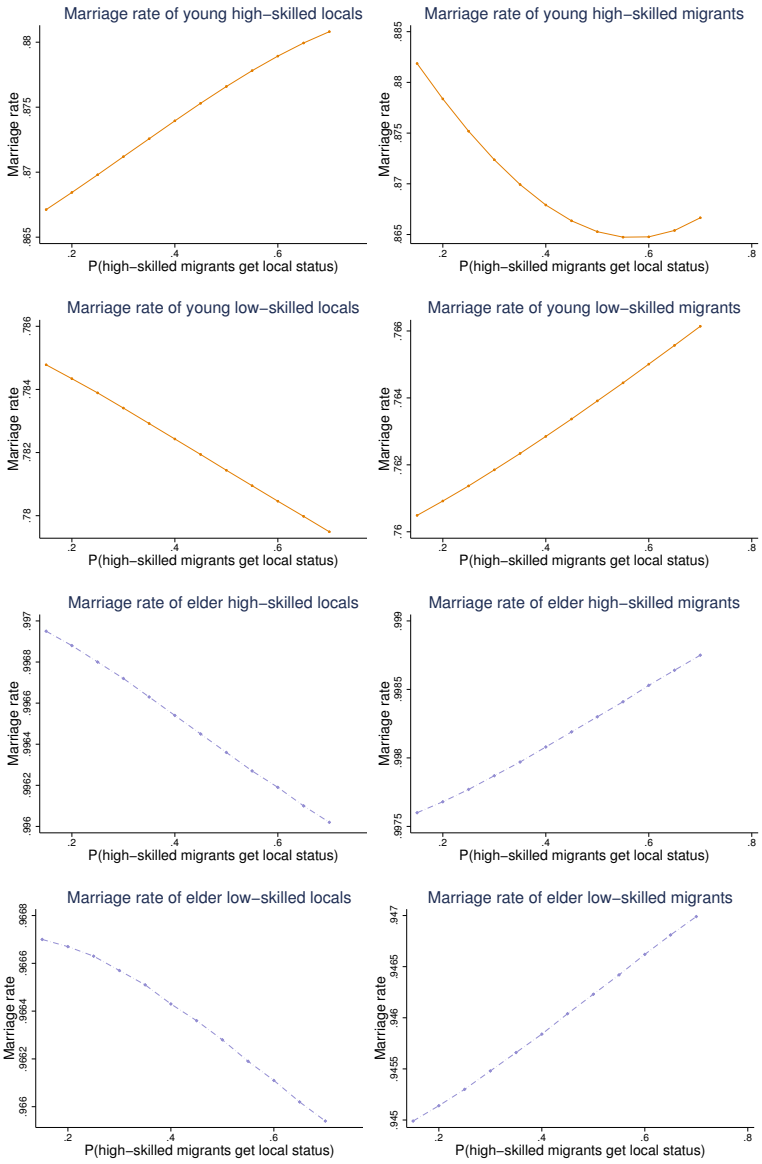
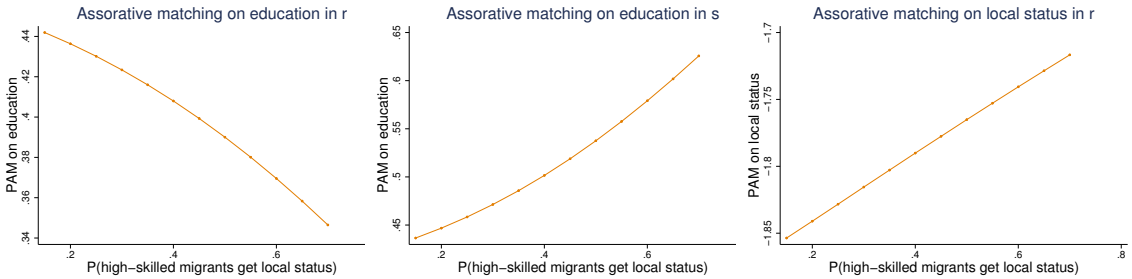


Figure B.2: Comparative statics of matching pattern



determination of location choice probability p_t and q_t. Ψ is defined in the interior of the simplex $\Delta^{\Sigma_m(D^m-1)+\Sigma_f(D^f-1)}$ such that

$$\Delta^{\Sigma_m(D^m-1)+\Sigma_f(D^f-1)} = \{p_t^1, ...p_t^{\dim(\mathscr{M})}, q_t^1, ..., q_t^{\dim(\mathscr{F})} | \sum_{1\le d\le D^m} p_t^{m|d} = 1, \sum_{1\le d\le D^f} q_t^{f|d} = 1, \forall m \forall f\}.$$

The details of the mapping function are as follows. Denote N_t^m as the initial population of type m men at period t and N_t^f as that of type f women. Denote $N_t^{m|d}$ and $N_t^{f|d}$ as the population composition after migration and before marriage decisions. $N_t^{m|d}$ and $N_t^{f|d}$ are determined by the LCPs and initial distribution of singles, N_t^m and N_t^f:

$$N_t^{m|d} = p_t^{m|d} N_t^m$$

$$N_t^{f|d} = q_t^{f|d} N_t^f$$

The marriage market equilibrium can then be solved by the interaction explained in section 2.A. Denote $n_t^{m\overline{f}|d}$ as the number of type m men choosing spouse type $\overline{f}$ and $n_{\overline{f}m|d^t}$ as that of type f women choosing type $\overline{m}$ spouse. $n_t^{m\overline{f}|d}$, $n_{\overline{f}m|d^t}$, and the expected utility from the marriage market before the realization of idiosyncratic spouse-type marriage preference are determined by the marriage market equilibrium.

Denote $EU_t(m,0)$ as the expected utility of type m single men at the beginning of period t before the realization of location preference, $EV_t(0,f)$ as that of type f women, and $E\pi_t(m,f)$ as the joint expected utility of a couple (m,f). Denote $EU_t(m,0|d)$ as the expected utility of type m single men choosing location d just before the realization of marriage preference and $EV_t(0,f|d)$ as that of type f single women. Denote $U_{d,t}^{m,\overline{f}}$ and $V_{d,t}^{\overline{m},f}$ as the choice-specific utility of choosing spouse type $\overline{f}$ and $\overline{m}$. The expected utilities before the realization of marriage preference $EU_t(m,0|d)$ and $EV_t(0,f|d)$ satisfy:

$$EU_t(m,0|d) = U_t^{m0|d} + log(\frac{N_t^{m|d}}{n_t^{m0|d}})$$

$$EV_t(0,f|d) = U_t^{0f|d} + log(\frac{N_{d,t}^f}{n_d^{0f}})$$

N_t^m and N_t^f of those of age category $a=2$ can be computed using an loop outside the marriage market equilibrium iteration given LCPs, transition function TF, and the expected utilities EU and EV.

In the end, the updated LCPs can be computed using the equations:

$$p_t^{m|d} = \frac{exp(EU_t(m,0|d) - c_t^{d|h^m})}{\sum_{d'} exp(EU_{d',t}(m,0) - c_t^{d'|h^m})}$$

$$q_t^{f|d} = \frac{exp(EV_t(0,f|d) - c_t^{d|h^f})}{\sum_{d'} exp(EV_{d',t}(0,f) - c_t^{d'|h^f})}$$

From the details of the mapping function above, Ψ is not defined if there exists an m and d such that $p_t^{m|d} = 0$ or an f and d such that $q_t^{f|d} = 0$. To make the mapping function Ψ continuous on $\Delta^{\sum_m (D^m-1)+\sum_f (D^f-1)}$, I extend the mapping function in the following way. Assume L_m is the number of $p_t^{m|d}, d \in \{1,...,D^m\}$ that is equal to zero, L_f is the of number of $q_t^{f|d}, d \in \{1,...,D^f\}$ that is equal to zero, and $L = \sum_m L_m + \sum_f L_f$. Pick a sequence of $\{p^{n,t}, q^{n,t}\}$ where $p^{n,t} = \{p_m^{n,t}\}_m$, $q^{n,t} = \{q_f^{n,t}\}_f$, $p_m^{n,t} = \{p_{m,d,t}^n\}_{d \in D^m}$ and $q_f^{n,t} = \{q_{f,d,t}^n\}_{d \in D^f}$. The sequence satisfies the following conditions:

$$p_{m,d,t}^n = \begin{cases} \varepsilon \to 0 & \text{as } n \to \infty \text{ if } \quad p_t^{m|d} = 0 \\ p_t^{m|d} - \frac{\varepsilon L_m}{D^m - L_m} & \text{if} \qquad p_t^{m|d} \neq 0 \end{cases}$$

$$q_{f,d,t}^n = \begin{cases} \varepsilon \to 0 & \text{as } n \to \infty \text{ if } \quad q_t^{f|d} = 0 \\ q_t^{f|d} - \frac{\varepsilon L_f}{D^f - L_f} & \text{if} \qquad q_t^{f|d} \neq 0 \end{cases}$$

Define $\Psi(p^t, q_t)$ to be equal to the limit of $\{\Psi(p^{n,t}, q^{n,t})\}$ which is finite given $\Psi(\cdot) \in \Delta^{\sum_m (D^m-1)+\sum_f (D^f-1)}$.

Based on the construction above, Brouwer's fixed point theorem ensures the existence of equilibrium. The left task is to prove that the fixed point $\{p_t*, q_t*\}$ satisfies the conditions that

$$\nexists m \nexists d, s.t. p_t^{m|d} = 0$$

and

$$\nexists f \nexists d, s.t. q_t^{f|d} = 0$$

. To begin with, if $\exists m \exists d, s.t. p_t^{m|d} = 0$, then either $EU_t(m,0|d) = -\infty$ or $\exists d' \neq d, s.t. EU_{d',t}(m,0) = \infty$. Either case requires that $\exists \{m, f, d, t' \geq t\}, s.t. U^{m,fd,t'} = \infty$, $V^{m,fd,t'} = -\infty, or\ U^{m,fd,t'} = -\infty$, $V^{m,fd,t'} = \infty$, because the flow utility of staying single is finite. However, the above requirements violate the marriage market clearing conditions and the property of marriage matching equilibrium. For example, if $U^{m,fd,t'} = \infty$ and $V^{m,fd,t'} = -\infty$, the marriage market would not clear if $\overline{m}^{d,t'} > 0$, but $\overline{m}^{d,t'} > 0$ if $U^{m,fd,t'} = \infty$.

Appendix 2.D Specification of migration cost and marriage preference

The details of migration cost and marriage preference are as follows:

- **migration cost**

$$
\begin{aligned}
c_t^{d|h^m} =& [1 + c^{mid}\mathbb{1}_{mid}(e^m) + c^{high}\mathbb{1}_{high}(e^m)] \times (1 + c^{2005}\mathbb{1}_{2005}(t)) \times \\
& [c^0\mathbb{1}_{loc}(h^m,d) + c_t^{type}\mathbb{1}_{type}(h^m,d) + c_t^{region}\mathbb{1}_{region}(h^m,d) + c_t^3\mathbb{1}_{region}(h^m,d)Dis(h^m,d) \\
& + c_t^4\mathbb{1}_{type}(h^m,d)Dis(h^m,d)]
\end{aligned}
$$

$$
\begin{aligned}
c_t^{d|h^f} =& [1 + c^f + c^{mid}\mathbb{1}_{mid}(e^f) + c^{high}\mathbb{1}_{high}(e^f)] \times (1 + c^{2005}\mathbb{1}_{2005}(t)) \times \\
& [c^0\mathbb{1}_{loc}(h^f,d) + c_t^{type}\mathbb{1}_{type}(h^f,d) + c_t^{region}\mathbb{1}_{region}(h^f,d) + c_t^3 Dis(h^f,d)\mathbb{1}_{region}(h^f,d) \\
& + c_t^4\mathbb{1}_{type}(h^f,d)Dis(h^f,d)]
\end{aligned}
$$

where c^f captures the relative migration cost of women compared to men, c^{mid} captures the relative migration cost of those with high school/technical education compared to those with less than high school education, c^{high} captures the relative migration cost of the high-skilled migrants compared to the low educated migrants, $\mathbb{1}_{2005}(t)$ captures the change in migration cost from 2000 to 2005, $\mathbb{1}_{loc}$, $\mathbb{1}_{type}$ and $\mathbb{1}_{region}$ are dummies of migrating away from the current location,location type (rural/small cities/big cities/mega cities) and big region, $Dis(h^m,d)$ measures geographical distance between the place of hukou registration and the destination and is approximated by the average of distance from each preference within location h^m to each one within location d.

- **marital surplus from marriage preference**:

$$
\begin{aligned}
& marrypref(m,f) \\
& = \eta^0 + \eta_u^0\mathbb{1}_u(d) + \eta_{bu}^0\mathbb{1}_{bu}(d) + \eta^{high}(\mathbb{1}_{high}(e_m) + \mathbb{1}_{high}(e_f)) + \eta^{mid}(\mathbb{1}_{mid}(e_m) + \mathbb{1}_{mid}(e_f)) \\
& + \eta_{mf}^h\mathbb{1}\{h^m = h^f = d\} + \eta_{m0}^h\mathbb{1}\{h^m = d, h^f \neq d\} + \eta_{0f}^h\mathbb{1}\{h^m \neq d, h^f = d\} + \eta_1^e\mathbb{1}\{e^m > e_f\} \\
& + \eta_{-1}^e\mathbb{1}\{e^m < e_f\} + \eta_1^a\mathbb{1}\{a^m > a_f\} + \eta_{-1}^a\mathbb{1}\{a^m < a_f\} + \eta^h\mathbb{1}\{h^m \neq h^f\} \\
& + \eta^{region}\mathbb{1}\{region_m \neq region_f\}
\end{aligned}
$$

where η^0 is a constant capturing the marital surplus of the baseline case (marriage between two migrants with all the characteristics the same), η_u^0 is a constant similar to η^0 but relevant only in cities, η_{bu}^0 is a constant only relevant in large cities, η^{high} captures the

difference in marriage rate for highly educated individuals with respect to those with less than a high school education, η^{mid} is for the difference in marriage rate of those with high school/technical education, η^h_{mf} is the relative utility if the couples have local hukou, η^h_{m0} is that if only the husband has local hukou, η^h_{0f} is that if only the wife has local hukou, η^e_1 is the relative utility if the husband has higher education than the wife, η^e_{-1} is that if the husband has lower education, η^a_1 is the relative utility if the husband is elder than the wife, η^a_{-1} is that if the husband is younger, η^h is the relative utility if the couples are from different places of registration, and η^{region} is the relative utility if the couples are from different big regions.

The corresponding estimates of the variables are summarized in the Table D.1.

Table D.1: Parameters of flow utility-part

Variables	Coefficient	SE
Single utility		
Disutility of moving c^0	4.31	0.02
Disutility of moving to a different type of region c^1	1.18	0.01
Disutility of moving out of the big region c^2	-0.16	0.01
Disutility from Distance (1000km) × Moving between big regions c^3	0.33	0.01
Disutility from Distance (1000km) × Moving between rural and urban	1.31	0.01
Relative mig. cost of the highly educated in 2000 c^{high}	-0.49	0.003
Relative mig. cost if without middle level of education in 2000 c^{middle}	-0.22	0.001
Relative mig. cost of the highly educated in 2005 c^{high}	-0.41	0.003
Relative mig. cost if without middle level of education in 2005 c^{middle}	-0.24	0.002
Ratio of mig. cost of year 2005 with respect to 2005 c^{2005}	0.99	0.002
Marital surplus		
marriage preference of the highly educated individuals	-0.48	0.02
marriage preference of ones with high school/technical education	-0.40	0.004
Marrying spouses of the same characteristics with respect to being single in 2000 η^0	-0.58	0.03
Marrying spouses of the same characteristics with respect to being single in 2005 η^0	-1.99	0.04
Marrying spouses of the same characteristics in cities η^0_u	-0.23	0.01
Marrying spouses of the same characteristics in large cities η^0_{bu}	-0.54	0.01
Both are locals η^h_{mf}	0.63	0.01
intermarriage with locals for female migrants η^h_{m0}	0.52	0.03
intermarriage with locals for male migrants η^h_{0f}	-0.92	0.03
Education difference (M>F) η^e_1	-1.10	0.004
Education difference (M<F) η^e_{-1}	-3.00	0.01
Age difference (M>F) η^a_1	-1.20	0.01
Age difference (M<F) η^a_{-1}	-2.28	0.01
Couple from different location η^h	-1.64	0.02
Couple from different big regions η^{region}	-0.79	0.01

The coefficients and standard errors are rounded to two decimal places. The standard errors are computed from the hessian matrix without the correction for the first stage estimations of wage and state transitions.

Appendix 2.E Identification of utility parameters

Recall that individual utility includes two parts: one part universal to individuals regardless of marital status and the other part is marital surplus, the additional utility from marriage. The continuation value of those with $a = 3$ is currently assumed to be zero. The continuation value of the younger cohorts can be written as a function of the conditional choice probabilities (CCP) observed from the choices of the elder using Hotz Miller inversion. The CCPs are directly computed from the observed data. For those choosing being single, the continuation value satisfies

$$\beta \sum_{m'} TF_t(m', 0|m, 0, d) EU_{t+1}(m', 0)$$

$$EU_{t+1}(m', 0) = U_{h_{m'},t}^{m',0} - log(p_t(0, h_{m'}|m'))$$

where m' is new type after the transition of state vector, $U_{h_{m'},t}^{m',0}$ is the utility of staying single at the place of registration, and $-log(p_t(0, h_{m'}|m'))$ is the expected utility relative to the single utility at home and is a function of the share of m' individuals choose staying single at home at time t. For those forming marriages, the continuation value

$$\beta \sum_{m'} \sum_{f'} TF_t(m', f'|m, f, d) E[U_{t+1}(m', f') + V_{t+1}(m', f')]$$

$$E[U_{t+1}(m', f') + V_{t+1}(m', f')] = U_{h_{m'},t}^{m',f'} + V_{h_{m'},t}^{m',f'} - log(\frac{p_t(f', h_{m'}|m')}{\sum_d p_t(f', d|m')})$$

where $U_{h_{m'},t}^{m',f'} + V_{h_{m'},t}^{m',f'}$ is the joint household utility at the home location of the husband, and $\frac{p_t(f', h_{m'}|m')}{\sum_d p_t(f', d|m')}$ is the observed probability of choosing to stay at the home of the husband given the wife is of type f'. If one partner exits next period and the other one remains in the model, the future expected utility is computed using the single utility without the options of re-entering the marriage market.

The utility independent of marital surplus can be further divided into three components: one universal to all residents such as regional amenity and wage utility, one specific to those with local hukou such as hukou benefits, and the one specific to migrants such as migration cost. This part of identification is based on location choices of those staying single. For individuals with the age and education but migrating from different places to the same destination, the difference in choice probabilities relative to staying at home gives the difference in migration cost and hukou benefit. Thus, I identify the parameters of migration cost mainly by changing the destinations and identify the differences in hukou benefits by changing the home regions. For the same type of individuals, the difference in probabilities of migrating from the same place to different

destinations gives the difference in amenity, wage, migration cost, and future expected utility. If I further compare the differences for different types of individuals, it help me to identify the difference in amenity, parameters of wage, and those affecting future expected utility.

$log(\frac{p_t(0,d|m)}{p_t(0,d'|m)})$ is the difference in the utility of a type m men who choose between location d and d' and remaining single. If both locations are not the home region and $a=3$, I have

$$\begin{aligned} log(\frac{p_t(0,d|m)}{p_t(0,d'|m)}) &= u_t^{m0|d} - u_t^{m0|d'} - c_t^{d|h^m} + c_t^{d'|h^m} \\ &= [K_{d,t}^{single}(m,0) - K_{d',t}^{single}(m,0)] - (c_t^{d|h^m} - c_t^{d'|h^m}) \\ &= (1+\gamma^{mid}\mathbb{1}_{mid}(e^m)+\gamma^{high}\mathbb{1}_{high}(e^m))(1+\gamma^{2005}\mathbb{1}_{2005}(t))(\gamma_d-\gamma_{d'})+\gamma^m(\hat{w}_t^{m|d}-\hat{w}_{d't}^m)-(c_t^{d|h^m}-c_t^{d'|h^m}) \end{aligned} \tag{2.5}$$

To begin with, I start with the parameters of migration cost. Pick two types of men m and m' such that $e=low$, $a=3$ and $h\neq d,d'$. As long as both of them have rural hukou or urban hukou, the amenity term and the wage term cancel out if I compare $log(\frac{p_t(0,d|m)}{p_t(0,d'|m)})$ and $log(\frac{p_t(0,d|m')}{p_t(0,d'|m')})$. The left terms are

$$\begin{aligned} &log(\frac{p_t(0,d|m)}{p_t(0,d'|m)}) - log(\frac{p_t(0,d|m')}{p_t(0,d'|m')}) \\ =&[1+c^{mid}\mathbb{1}_{mid}(e^m)+c^{high}\mathbb{1}_{high}(e^m)]\times c^{2005}\mathbb{1}_{2005}(t)\times\{c^{region}[\mathbb{1}_{region}(h^m,d')-\mathbb{1}_{region}(h^m,d)] \\ &+c^3[Dis(h^m,d')-Dis(h^m,d)]+c^4[\mathbb{1}_{type}(h^m,d)Dis(h^m,d')-\mathbb{1}_{type}(h^m,d)Dis(h^m,d)]\} \end{aligned}$$

Thus, by changing d and d', I can first identify c^{region}, c^3, and c^4 for the migrants with less than high school education in 2000. Then I can identify c^{mid}, c^{high}, and c^{2005} by changing the education level of migrants and the year of data.

At the second step, I focus on male migrants only differing in having urban hukou or rural hukou and with $a=3$. The amenity term cancels out.

$$\begin{aligned} &log(\frac{p_t(0,d|m)}{p_t(0,d'|m)}) - log(\frac{p_t(0,d|m')}{p_t(0,d'|m')}) \\ =&\gamma^m(\hat{w}_t^{m|d}-\hat{w}_{d't}^m-\hat{w}_{dt}^{m'}+\hat{w}_{d't}^{m'}) \\ &+[1+c^{mid}\mathbb{1}_{mid}(e^m)+c^{high}\mathbb{1}_{high}(e^m)]\times c^{2005}\mathbb{1}_{2005}(t)\times[c_t^{type}(\mathbb{1}_{type}(h^m,d')-\mathbb{1}_{type}(h^m,d)) \\ &+c_t^{region}(\mathbb{1}_{region}(h^m,d')-\mathbb{1}_{region}(h^m,d))+c_t^3(Dis(h^m,d')-Dis(h^m,d)) \\ &+c_t^4(\mathbb{1}_{type}(h^m,d)Dis(h^m,d')-\mathbb{1}_{type}(h^m,d)Dis(h^m,d))] \end{aligned}$$

Based on what have been identified before, I can first identify γ^m by changing locations d and d' and further identify c_t^{type} that is the only term left to be identified. γ^f and c^f can be identified in a similar way using the choices of women.

Third, based on the parameters identified above, I can further identify the difference in regional amenity ($\gamma_d - \gamma_{d'}$) and the relative amenity by education level and year, γ^{mid}, γ^{high}, and γ^{2005}, can be identified from the difference in $log(\frac{p_t(0,d|m)}{p_t(0,d'|m)})$ for different combinations of d and d' that are different from the place of registration.

However, the identification of the constant cost of migration c^0 needs further discussion. The expression below is the difference in choice share of migrating to location d and staying in the place of registration for type m men aged 31-35.

$$
\begin{aligned}
&log(\frac{p_t(0,d|m)}{p_t(0,h^m|m)}) = u_t^{m0|d} - u_{h^m,t}^{m,0} - c_t^{d|h^m} \\
&= [K_{d,t}^{single}(m,0) - K_{d',t}^{single}(h^m,0)] - c_t^{d|h^m} - g_{d,t}^{single}(h^m) \\
&= (1+\gamma^{mid}\mathbb{1}_{mid}(e^m) + \gamma^{high}\mathbb{1}_{high}(e^m))(1+\gamma^{2005}\mathbb{1}_{2005}(t))(\gamma_d - \gamma_{h^m}) + \gamma^m(\hat{w}_t^{m|d} - \hat{w}_{h^m t}^m) - c_t^{d|h^m} - \delta_{h^m}
\end{aligned}
$$

where hukou benefit plus constant migration cost $\delta_t^{h^m} + c^0$ is jointly identified and thus only $\delta_d - \delta_{d'}$ and δ^{2005} are identified by comparing different h^m.

The difference in hukou benefit can also be identified using the change in policy variation and the location choice probabilities of individuals aged 26-30 and staying single under different policies. Let m" be the same as m except for the age category, s.t. $a_{m"} = a^m + 1$.

$$
\begin{aligned}
&log(\frac{p_t(0,d|m)}{p_t(0,h^m|m)}) \\
=&u_t^{m0|d} - c_t^{d|h^m} + \beta\sum_{m'} TF_t(m',0|m,0,d)EU_{t+1}(m',0,\xi) - u_{h^m,t}^{m,0} - \beta EU_{t+1}(m'',0,\xi) \\
=&u_t^{m0|d} - c_t^{d|h^m} + \beta\sum_{m'} TF_t(m',0|m,0,d)[u_{h_{m'},t}^{m',0} - log(p_t(0,h_{m'}|m'))] - u_{h^m,t}^{m,0} - \beta[u_{h^m,t}^{m'',0} - log(p_t(0,h_m|m''))] \\
=&(1+\gamma^{mid}\mathbb{1}_{mid}(e^m) + \gamma^{high}\mathbb{1}_{high}(e^m))(1+\gamma^{2005}\mathbb{1}_{2005}(t))(\gamma_d - \gamma_{h^m}) + \gamma^m[log(\hat{w}_{d,t}^m) - log(\hat{w}_{h^m,t}^m)] - \delta_t^{h^m} \\
&- c_t^{d|h^m} + \beta\sum_{m'} TF_t(m',0|m,0,d)[u_{h_{m'},t}^{m',0} - log(p_t(0,h_{m'}|m'))] - \beta[u_{h^m,t}^{m'',0} - log(p_t(0,h_m|m''))]
\end{aligned}
$$

Thus, comparing $log(\frac{p_t(0,d|m)}{p_t(0,h^m|m})$ for different t gives me the following variation after taking away all the elements identifiable before (wage, amenity difference, migration cost, and sum of amenity and constant migration cost):

$$[TF_t(m',0|m,0,d) - TF_{t+1}(m',0|m,0,d)](\delta_t^d - \delta_t^{h^m})$$

Thus the difference in hukou reforms over time and across regions help me identify the difference in hukou benefits between locations $\delta_d - \delta_{h^m}$.

Last, the identification of the levels of hukou benefit replies on the policy of land allocation

in China. In 1998, there was a nationwide allocation of land based on household composition in the rural areas, of which few changes were made afterwards even if the household composition changed. Daughters did not take land away after marriage. However, if households transfer or convert hukou to elsewhere, the land may be taken away by the community. There is also literature that studies how land insecurity impedes rural-urban migration even if the migrants do not intend to change the hukou (Giles and Mu, 2018; De La Rupelle et al., 2009). Here I do not include the measure of location-specific degree of land insecurity. What I choose instead is to assume the benefit extension to intermarriage in rural areas is zero. Additional details are stated below.

The parameters of the marital surplus can be identified using the relative spouse choice share with respect to the percentage of individuals staying single by type. Note that

$$log(\frac{p_t(f,d|m)}{p_t(0,d|m)}) + log(\frac{q_t(m,d|f)}{q_t(0,d|f)}) = Z_t^{mf|d}$$

The chosen baseline is the case where individuals stay in the place of registration and choose spouses with the same characteristics as themselves. The marital surplus of the baseline is captured by η^0.

To begin with, the parameter of supermodularity in income can be identified by comparing the relative choice probabilities of choosing certain types of spouses with respect to staying single in different locations. For example, for individuals aged 31-35, choose two combinations of couples with the same ages and education levels but with different places of registration. Let $h^f = h^m = d$ and $h_{f'} = h_{m'} = d'$.

$$z_t^{mf|d} - z_{d',t}^{m',f'} = \gamma_t^{mf}(\hat{w}_t^{m|d} + \hat{w}_t^{f|d} - \hat{w}_{d't}^{m} - \hat{w}_{d't}^{f}) + \gamma^{sup}[log(\hat{w}_t^{m|d})log(\hat{w}_t^{f|d}) - log(\hat{w}_{d't}^{m'})log(\hat{w}_{d't}^{f'})]$$

Second, the parameters of marriage preference can be identified by comparing the probabilities that individuals choose spouses with different characteristics in the same location. For example, if $f \neq f'$, $a_f = a_{f'}$ and $h^f = h_{f'}$, for those aged 31-35,

$$\begin{aligned} z_t^{mf|d} - z_{d,t}^{m,f'} =& \gamma_t^{mf}(\hat{w}_t^{f|d} - \hat{w}_{d't}^{f}) + \gamma^{sup} log(\hat{w}_{d,t}^{m})[log(\hat{w}_{d,t}^{f}) - log(\hat{w}_{d,t}^{f'})] \\ &+ \eta_1^e(\mathbb{1}\{e^m > e_f\} - \mathbb{1}\{e^m > e_{f'}\}) + \eta_{-1}^e(\mathbb{1}\{e^m < e_f\} - \mathbb{1}\{e^m < e_{f'}\}) \end{aligned}$$

Similarly, η^es, η^as and η^r can be identified.

Third, η^0, η_u^0, and η_{bu}^0 can by identified by comparing the probability of migrants marrying spouses with the same characteristics to that of staying single in different locations.

Fourth, by comparing the choice probability of marrying migrants and marrying locals in different locations and years given that the other characteristics are the same, I can identify b_{IM}^m,

b^f_{IM}, η^h, b^m, b^p, η^{mf}, η^{m0} and η^{0f}. The current assumption is that the baseline marital surplus equals to that of couples both are migrants. Denote $\overline{\eta} = \eta^0 + \eta^0_u \mathbb{1}_u(d) + \eta^0_{bu} \mathbb{1}_{bu}(d)$. There are five potential types of couples and the associated marital surplus are as follows: 1) M citizen - F citizen $\overline{\eta} + \eta^{mf}$, 2) M citizen - F migrant $\overline{\eta} + \eta^{m0} + \eta^h + (b^m + b^p Policy_{d,t})\delta_d \mathbb{1}_{urban}(h^m)$, 3) M migrant - F citizen $\overline{\eta} + \eta^{0f} + \eta^h + (b^f + b^p Policy_{d,t})\delta_d \mathbb{1}_{urban}(h^f)$, 4) M migrant - F migrant from the same source location $\overline{\eta}$, and 5) M migrant - F migrant from different source locations $\overline{\eta} + \eta^h$. Comparing type 4) with type 5), η^h is identified. With time variation in spouse policies, b^p can be identified, because $\delta_d - \delta_{d'}$ is identified above. With different locations d, b^m and b^f can also be separately identified. The comparison between different types of couples in rural areas identifies η^{m0}, η^{0f} and η^{mf}.

Appendix 2.F Summary of the estimation of wage equations

The first table shows the GDP ratio and CPI used to compute real wage for each location in 2000 and 2005. The CPI equals to location-specific CPI divided by population-weighted CPI of all regions. The GDPPC ratio equals to location-specific GDPPC in 2000 divided by that in 2005.

Table F.2: Details of wage adjustment

Year	Obs	Mean	Std. Dev	Min	Max
		CPI			
2000	26	0.89	0.17	0.58	1.28
2005	26	0.94	0.17	0.62	1.33
		GDPPC ratio			
2000	26	0.77	0.10	0.51	1.01

The second table summarizes the main information on the wage estimation by location using Population Census 2005, including the summary statistics of wage, the coefficients of variables, and the average predicted wage.

Table F.3: Summary of wage equations

Loc.	Nobs	**Mean wage**		Coefficients								R^2	**Predict. wage**		**Area**
		M.	F.	Cons.	Eduy	FEduy	Age	Age2	F.	R.HK	Mig.	R.Mig		M.	F.	
Rural areas																
1	42171	475.6	325.2	5.70	0.03	0.00	0.03	-0.0004	-0.38	-0.43	0.00	0.49	0.13	599.6	396.5	Northeast
2	57113	504.4	316.0	6.15	0.04	-0.02	0.02	-0.0003	-0.31	-0.55	0.00	0.51	0.16	681.3	418.8	North Coast
3	30439	881.9	541.6	5.90	0.04	0.01	0.03	-0.0005	-0.52	0.00	0.27	-0.03	0.21	753.0	473.3	Central Coast
4	77467	538.5	370.6	6.40	0.04	0.00	0.01	-0.0002	-0.28	-0.72	0.00	0.75	0.21	656.5	471.6	South Coast
5	137727	443.7	274.6	6.10	0.04	-0.02	0.02	-0.0003	-0.30	-0.72	0.00	0.66	0.15	681.7	416.6	Central region
6	102057	363.9	254.7	4.23	0.06	-0.01	0.03	-0.0004	-0.20	0.00	0.13	0.37	0.12	225.4	157.9	Northwest
7	138790	302.1	237.4	4.66	0.07	-0.01	0.03	-0.0004	-0.06	-0.34	0.00	0.64	0.10	311.8	245.4	Southwest
Small cities																
8	30046	757.5	629.3	5.12	0.08	0.03	0.03	-0.0003	-0.55	-0.08	0.22	0.00	0.24	591.5	418.3	Northeast
9	32610	801.2	545.5	4.94	0.08	0.03	0.03	-0.0004	-0.64	0.13	0.16	0.00	0.28	560.7	350.4	North Coast
10	30411	1217.6	851.4	5.55	0.07	0.02	0.04	-0.0005	-0.52	-0.01	0.17	0.00	0.25	912.0	608.5	Central Coast
11	83622	1000.9	739.3	5.42	0.08	0.02	0.03	-0.0005	-0.38	-0.06	0.36	0.00	0.25	842.3	613.8	South Coast
12	70283	763.5	545.0	4.79	0.08	0.03	0.05	-0.0006	-0.61	-0.08	0.32	0.00	0.29	581.3	378.8	Central region
13	42819	848.3	635.5	4.39	0.11	0.02	0.06	-0.0007	-0.45	-0.09	0.50	0.00	0.33	667.1	452.6	Northwest
14	40088	665.3	497.5	3.97	0.12	0.00	0.06	-0.0007	-0.23	-0.03	0.40	0.00	0.36	506.8	369.4	Southwest
Big cities																
15	12924	951.0	812.5	5.36	0.10	0.03	0.02	-0.0002	-0.47	-0.08	0.28	0.00	0.29	742.1	525.9	Northeast
16	7261	1058.0	810.5	5.02	0.10	0.02	0.03	-0.0004	-0.51	0.00	0.17	0.13	0.31	671.1	455.0	North Coast
17	9329	1511.6	1147.5	5.74	0.08	0.02	0.03	-0.0004	-0.40	0.01	0.00	0.00	0.33	1172.1	833.5	Central Coast
18	6082	1259.4	1001.8	5.17	0.08	0.02	0.05	-0.0005	-0.37	0.03	0.06	0.00	0.30	876.4	657.4	South Coast
19	15199	1033.7	822.3	5.20	0.09	0.03	0.04	-0.0004	-0.59	0.03	0.15	0.00	0.30	764.4	514.2	Central region
20	15150	959.3	783.1	4.50	0.11	0.04	0.05	-0.0005	-0.62	0.06	0.23	0.00	0.36	651.7	433.7	Northwest
21	11684	928.6	739.5	4.25	0.12	0.02	0.06	-0.0006	-0.37	0.00	0.37	0.00	0.39	655.4	469.7	Southwest
Mega cities																
22	19573	1650.7	1471.1	5.23	0.12	0.02	0.04	-0.0005	-0.46	-0.41	0.09	0.32	0.45	925.2	655.4	Beijing
23	33144	1101.8	1000.7	5.71	0.05	0.00	0.04	-0.0006	-0.08	-0.04	0.08	0.00	0.14	893.0	763.5	Tianjin
24	35694	1640.7	1387.0	5.65	0.10	0.01	0.03	-0.0004	-0.26	-0.14	0.05	0.05	0.39	1046.3	800.5	Shanghai
25	10951	813.2	593.5	4.51	0.10	0.02	0.03	-0.0004	-0.50	0.30	0.22	0.00	0.34	438.7	297.0	Chongqin-urban
26	34477	1794.9	1446.9	4.77	0.13	0.01	0.06	-0.0008	-0.24	-0.12	0.07	0.00	0.41	1110.9	853.5	Guangzhou/ Shenzhen

The table contains information on wage estimation in each location d. "F." means female, "R." means rural hukou, "Mig." means migrant, and "M." means male.

Appendix 2.G Descriptive statistics of Data

Statistical yearbooks

Table G.4: Summary statistics of prefecture characteristics

Variable	Obs	Mean	Std. Dev.	Min	Max
	Year 2000				
Urbanization rate	261	.30	.17	.10	.84
GDP per capita (CNY)	261	8381	9460	1479	122180
Population density (person/km^2)	261	423.65	303.89	24.33	2323.67
ToPort (1000km)	261	.48	.40	.02	2.73
	Year 2005				
Urbanization rate	284	.32	.17	.08	.91
GDP per capita (CNY)	284	12834	15525	2152	201176
Population density (person/km^2)	284	415.63	341.22	4.81	2781.77
ToPort (1000km)	284	.44	.41	.02	2.73
	Year 2010				
Urbanization rate	285	.35	.18	.08	.99
GDP per capita (CNY)	285	27840	30746	3864	334215
Population density (person/km^2)	285	418.89	311.40	4.90	2458.89
ToPort (1000km)	285	.45	.42	.02	2.73

The maximum of GDP per capita for each year is the GDPPC in Shenzhen.

China Labor-force Dynamics Survey

Table G.5: Summary statistics of migrants characteristics in CLDS

	1st year		2nd-5th years (no local hukou in the 1st year)	
Variable	Mean	Standard Deviation	Mean	Standard Deviation
Obtain local hukou	0.18	(0.38)	0.05	0.22
Female	0.55	(0.50)	0.52	0.50
Age	25.83	(8.52)	26.14	8.44
Rural(destination)	0.35	(0.48)	0.34	0.47
Rural Hukou	0.76	(0.43)	0.81	0.39
$\leq$ Middle school	0.58	(0.49)	0.60	0.49
High school/technical edu.	0.29	(0.45)	0.27	0.45
$\geq$ College	0.08	(0.27)	0.07	0.26
Spouse with local hukou	0.14	(0.34)	0.09	0.28
Observations	2392		1883	

Single rate

Table G.6: Single rate

	Men			Women		
	21-25	26-30	31-35	20-24	25-29	30-34
2000	0.70	0.20	0.07	0.61	0.1	0.015
2005	0.73	0.26	0.09	0.62	0.15	0.03
2010	0.78	0.32	0.12	0.70	0.24	0.06

Appendix 2.H Determinants of hukou reforms

The correlation between hukou reform indexes and regional characteristics is summarized in Table H.7. The regional characteristics are the average of 1998-2000 prefecture-level characteristics interacted with time trend. The urbanization rate is the share of population that has urban hukou, LnGDPPC is the log of GDP per employment, LnPD is the log of population density, LnPort is the log of distance to the ports, CityLevel is the administrative level of a city, with 3 being the provincial-level municipalities, 2 being the economically most vibrant cities, 1 being the other provincial capitals, and 0 being all other cities. The regression results show that compared to all the small cities, the time trend of advancement in provincial municipalities and most economic vibrant cities is slower. The trend associated with prefecture-level characteristics at the beginning of the reforms has very weak correlation with the hukou reform advancement, except for the distance to ports. The closer to the ports, the faster the advancement of reforms contingent on having local spouses.

Table H.7: Determinants of hukou reforms

VARIABLES	(1) MeritPolicy	(2) MeritPolicy	(3) SpousePolicy	(4) SpousePolicy
Urbanization rate x Trend		0.0168		-0.315
		(0.143)		(0.211)
LnGDPPC x Trend		-0.0369		-0.0192
		(0.0350)		(0.0516)
LnPopDensity x Trend		0.00938		-0.0175
		(0.0320)		(0.0472)
LnDistPort x Trend		0.0209		-0.174***
		(0.0196)		(0.0288)
BigCity x Trend	-0.141**	-0.138**	-0.183**	-0.125
	(0.0583)	(0.0696)	(0.0893)	(0.103)
Constant	0.777***	0.536	2.723***	5.051***
	(0.0225)	(0.531)	(0.0345)	(0.782)
Prefecture FE	√	√	√	√
Year FE	√	√	√	√
Observations	783	783	783	783
R-squared	0.764	0.766	0.812	0.828

Appendix 2.I Fit of model

Table I.8: Fit of model

Type	Actual share	Predicted share
Out-migration rate		
By location		
Rural	0.21	0.22
Small cities	0.11	0.11
Big cities	0.12	0.10
Mega cities	0.07	0.06
By education		
LowEdu	0.16	0.16
MidEdu	0.22	0.22
HighEdu	0.27	0.27
By gender		
Male	0.16	0.17
Female	0.19	0.19
Share of migrants to big/mega cities		
By education		
LowEdu	0.37	0.40
MidEdu	0.49	0.48
HighEdu	0.61	0.55
By gender		
Male	0.43	0.43
Female	0.41	0.43
Marriage rate rate		
By location		
Rural	0.48	0.44
Small cities	0.44	0.41
Big cities	0.37	0.35
Mega cities	0.29	0.30
By education		
LowEdu	0.47	0.43
MidEdu	0.36	0.34
HighEdu	0.40	0.39
By gender		
Male	0.41	0.38
Female	0.48	0.45
Intermarriage rate of citizens		
By location		
Rural	0.02	0.05
Small cities	0.10	0.10
Big cities	0.15	0.19
Mega cities	0.12	0.18
By education		
LowEdu	0.04	0.07
MidEdu	0.09	0.11
HighEdu	0.09	0.10
By gender		
Male	0.07	0.10
Female	0.04	0.05

Appendix 2.J Descriptive statistics of variables in reduced-form regressions

The following table summarizes the descriptive statistics of the important variables used in the reduced-form regressions, including the three dependent variables, measures of hukou reforms, and three controls used to mitigate the endogeneous implementation of hukou reforms. The first part is the summary statistics by pooling years 2000, 2005, and 2010. Each observation is a prefecture-year. The second part is those for the reduced-form regression on migration choice by gender. The third part is those for the reduced form regression on migration choice by marital status, gender and education. The final part is those for the regression on the degree of assortative matching on education and local hukou.

Variable	Obs	Mean	Std. Dev.	Min	Max
SpousePolicy	1,007	2.616	1.321	0	4
Log(PopDensity)	830	5.734	0.871	1.570	7.931
Log(GDPPC)	830	2.029	0.666	-1.009	4.051
share of self-employment	830	0.579	0.444	0.012	3.689
Migration overall					
Migration share	2,034	282.498	961.945	0	14,992
Migration by marital status					
Migration share	8,117	60.752	278.64	0	7,439

Chapter 3

Revealed Preference or Forced Leave: Migration Response to Pollution Information Disclosure (joint with Zichen Deng)[1]

3.1 Introduction

Poor environmental quality is a big challenge in developing countries, threatening individual health and well-being. Migration is one of individuals' leading choices to avoid harmful pollution threats. However, people in developing countries would under-react to surrounding pollution problems given information under-provision, suppression, and manipulation (Barwick et al., 2020). The first question that motivates our study is how pollution information disclosure affects individual migration response to air pollution? This pollution information disclosure can also help regulators to abate regional pollution. However, this also comes with spillover costs, such as pushing workers away. Therefore, the second-fold question we want to answer is how rising regulations affect individual migration decisions?

To answer the first question, we exploit the unique opportunity in China by combining the staggered implementation of a nationwide air quality monitor program in 2013-2015 in China and rich individual migration data from Population Census 2015. This program expanded geographical and pollutant coverage and provided real-time air quality information to the public. This program not only dramatically raised households' awareness about pollution issues (Barwick et al., 2020), but also shaped the enforcement activities of prefecture-level governments in China (Axbard and Deng, 2020). The program's roll-out is based on the administrative hierarchy and pre-determined designations. The rich information on individual characteristics and migration history from the 1% China Population Census 2015 allows us to exploit the policy variations to evaluate personal migration response to air pollution information disclosure.

[1] This chapter is based on **?**.

To answer the second question, we further exploit the characteristics of the Chinese political system – the discontinuity in mayors' incentives of pollution abatement after the program due to promotion age restriction. This is the first study that highlights the role of environmental regulations in individual migration responses to pollution information programs - worsening labor market conditions. By conducting mediation analysis in IV settings, we show that the regulation mechanism explains at least 30% of the total program impact on migration decisions. This result has an important implication on the welfare inference of information programs. Neglecting this mechanism, we would overestimate individual willingness to pay for clean air using migration responses and ignore the welfare losses due to the unintended impact of environmental regulations.

We begin by examining the average impact of the information program. Using an extended difference-in-differences model, we compare migration measures between prefectures with different initial air pollution levels. This program has reduced the population pollution elasticity by 0.04 at the prefecture-level. We find strong evidence of people leaving polluted prefectures but only observe a negligible decrease in the new arrival share. Since the information program includes three waves, our empirical strategy controls for wave-year fixed effects to ensure heterogeneity is not a threat to our identification. Our empirical strategy's key assumption is the parallel trends in migration outcomes between prefectures with different air pollution levels. We find no evidence that out-migration is greater in preceding years of the set up of air quality monitor. We further validate the results by showing the results are robust to potential measurement errors of migration data (Imbert et al., 2021) and confounding environmental policies.

We then examine the program impact by sub-populations divided by age, education, and rural/urban residence place. First of all, we find considerable heterogeneity across age groups. The young people (aged 21-40) are more affected than other age groups, while the elders (aged 61-80) are the least affected. The familiarity with digital technology and the mobility constraints are the potential reasons. Second, we observe a greater drop in population in counties than in cities, though monitors are mostly installed in cities. Since cities are usually more attractive destinations, this could happen when an individual utility drops similarly in counties and cities. Third, the difference in impact between individuals with different levels of education is little. Multiple mechanisms can rationalize the above heterogeneity results.

We consider two mechanisms and find supportive evidence correspondingly. The first and the most studied reason is the improved perception of health risk after real-time PM2.5 information is available for everyone. In line with Barwick et al. (2020), we found a sharp increase in the demand for pollution-related information by using internet searches of terms related to "smog". We also show that people perceive the neighboring air pollution problems to be more severe after

the program for a given level of actual air pollution. Finally, we use bilateral migration flows and Poisson pseudo-maximization likelihood (PPML) to confirm that people move to cleaner prefectures. Specifically, people living in more polluted prefectures have a higher tendency to move to cleaner prefectures due to the information program.

The second and novel mechanism of information impact is economic spillovers of environmental information. Recent studies such as Axbard and Deng (2020) and Greenstone et al. (2020) have documented an increase in regulation efforts from local governments on pollution abatement after the information program since these efforts become more observable for the central government. These environmental regulations often lead to job loss (Walker, 2013), which can have an independent effect on migration decisions. We first show that prefectures with high baseline pollution levels are regulated more strictly. Then, since mayors older than certain ages at the National People's Congress are less likely to be promoted, we show that prefectures with mayors below the age restriction experienced a larger increase in the out-migration rate in polluted prefectures.

Besides showing the relevance of the regulation mechanism, We quantify its importance using mediation analysis. Specifically, we use the discontinuities in promotion incentives to construct the instrumental variable (Frölich and Huber, 2017; Dippel et al., 2021) for the mediating variable, tightness of regulation. Our preferred estimates suggest that the pushing factor can explain around 30% of the total effect of the disclosure program. We attribute the remaining impact to the perception mechanism. Our results complement the previous literature by showing that the willingness-to-pay estimates would be overestimated substantially if one fails to consider the labor market change due to increased enforcement.

This paper contributes to several strands of the literature. First, our study is closely related to the works estimating the impact of air pollution on migration decisions, such as Bayer, Keohane and Timmins (2009*b*), Chen, Oliva and Zhang (2017), Chen, Oliva and Zhang (2018), Freeman et al. (2019), and Kim and Xie (2019). Though air pollution has received much attention in the literature, only a few works study its impact on individual migration decisions. This is mainly due to two difficulties. The first is the omitted variable bias resulting from the correlation between air pollution and unobserved regional characteristics important in migration decisions such as economic conditions. The instruments used in the literature, such as thermal inversion and pollutants from distant coal-fired power plants, mitigate but not solve this problem. [2] The

[2] The argument behind thermal inversion is that it intensifies air pollution by disrupting air movement and depends on the altitude uncorrelated with local economic activities. But besides altitude, the frequency of thermal inversion also depends on the distance to the coast, an important determinant of international trade openness. The reason behind using distant pollutants blown by the wind is that this pollutant is not correlated with local production activities. But distant pollutant still affects local air pollution-related environmental regulations since the checks from the central government towards the local governments are based on all the pollutants in the air. These issues are more severe for low-frequency outcomes such as migration decisions.

second difficulty is the lack of migration data with both migration information and a big sample size for geographical variations. Our paper avoids this problem by exploiting an information shock and predetermined air pollution level. Our results strengthen the previous findings by showing that air pollution does enter individual migration decisions. While this line of works often uses revealed choices to infer individual willingness to pay for clean air, we also highlight the importance of information in the preference inference.

Second, this paper further contributes to a growing literature on the impact of pollution information. Using the same air pollution information disclosure program, Axbard and Deng (2020) and Greenstone et al. (2020) analyze the impact on pollution regulation, Barwick et al. (2020) study the impact on mortality rate, credit card consumption, and housing price, and Wang and Zhang (2021) estimate the benefits of information using mask purchase transactions. Similar to us, Gao, Song and Timmins (2021) point out the underestimation of the value of clean air due to perception bias. However, in contrast to these studies, we study migration responses directly instead of relying on indirect measures such as housing prices to infer the long-term impact. Our key contribution is to introduce the environmental regulation mechanism and demonstrate the importance of examining multidimensional aspects of information disclosure.

This paper is also related to other literature. One strand of them examines the role of information in migration decisions. The subjects of information include social service (McCauley, 2019), earnings (Bryan and Morten, 2019), and employment opportunities (Porcher, 2019). Differently, we study the information on air quality, an essential component of amenity. Another strand of the literature study the impact of environmental regulations and mainly focus on firms' behaviors (Ambec and Lanoie, 2008; Brunnermeier and Levinson, 2004; Walker, 2011; Shapiro and Walker, 2018; He, Wang and Zhang, 2020). We instead relate environmental regulations to individual migration decisions.

The organization of the paper is as follows. We introduce the background of the information program in Section 2 and details of the data in Section 3. Section 4 presents the estimation strategy and summarizes the empirical results of total program impact on migration outcomes. Section 5 explores two mechanisms with a simple model and empirical evidence. Finally, Section 6 concludes the paper.

3.2 Background

Starting in 2013, the Ministry of Environmental Protection (MEP) rolled out new air quality disclosure requirements for 337 prefectures in three waves until 2015. These prefectures were required to install new, advanced air quality monitors and report newly revised indexes designed on the basis of recent research and technology progress. The aim is to inform the public and

guide air pollution abatement. This natural experiment creates information shocks that enable us to identify the impact of pollution information provision on avoidance behaviors - individual migration decisions in this paper. In this section, we introduce the details of the information program.

This nationwide air quality monitor installation program brought about a sudden and substantial improvement in public access to air pollution information. The improvement involves geographical coverage, pollutant type, warning standard, and frequency, with details elaborated below. Before 2013, only 113 big cities had installed old air quality monitors, which reported daily air pollution index according to the concentration of three pollutants (SO_2, NO_2, and PM_{10}). This air pollution reports raised little public attention because there were rarely severe warnings. One crucial reason is the neglect of $PM_{2.5}$, the particulate matter with 2.5 micrometers or less but much more detrimental to individual health than PM_{10} for a given concentration. $PM_{2.5}$ became one of the main pollutants due to the drastic increase in automobile possession and coal consumption, but was counted as PM_{10}.

MEP issued three documents in May 2012 requiring the listed prefectures to install new monitors and provide hourly air quality index (AQI). The starting dates that the reported AQI matters for the annual air quality evaluation are Jan 1st of 2013, 2014, and 2015 respectively. Hereafter, we refer to the three policies by waves 2013, 2014, and 2015. AQI follows a new air quality standard, which is more strict and based on more pollutants, SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3, and CO. The first wave included provincial capitals, municipalities, cities under separate state planning, and cities in Yangtza River Delta, Pearl River Delta, and Beijing-Tianjin-Hebei region. The second wave involved other 116 cities that were exemplary in or main targets of environmental protection. The third wave covered all the other prefectures. Figure A.1 demonstrates the geographical distribution of the program. The monitors were mainly installed in the urban area.

This program was shown to dramatically increase individual awareness of air pollution (Barwick et al., 2020) and to effectively motivate the local governments to regulate pollution emission (Axbard and Deng, 2020). Both channels are related to individual migration responses to this pollution information provision shock.

3.3 Data

We construct a unique dataset of migration using the 2015 Population Census, which is then linked to the information disclosure program of air quality. We also assemble a comprehensive supplementary dataset that includes air quality measures from satellite maps, enforcement records, age of mayors and party secretaries, online search index, and employment. Most of the

data are at the annual, prefecture level for 337 prefectures in 2011-2015, except for the individual employment data from Urban Household Survey.

Migration To quantify migration, we use the 15% sample of the representative 1% Population Survey in 2015 (2015 Mini-Census), collected by the National Bureau of Statistics. The sampling frame of the 2015 Census follows early waves of Mini-Census, which have also been used, among others, by Combes, Démurger and Li (2015); Facchini et al. (2019); Tombe and Zhu (2019*b*). The 2015 Mini-Census covers the entire population at their current residence, regardless of whether they hold local household registration (hukou), i.e., including migrants. The census contains information on demographics, migration history, and housing characteristics.

Census 2015 contains the most detailed migration history information among all the available Chinese population censuses and covers the whole period of the program. Similar to the previous 2005 Mini-Census, we observe the household registration type (agricultural or non-agricultural), place of registration, current place of residence (i.e., residence in 2015), and the time of and the main reason for leaving their current place of registration. Nevertheless, while the previous censuses only take record of individual province of residence one and five years ago, Census 2015 contains residence information at the county level in 2010 and 2014. Additionally, we observe both the time of living in the current place and the time of leaving the place of hukou registration, enabling us to document the step migration directly.

We combine these pieces of information to identify the place of residence for each individual in each year between 2010 and 2015. Then we construct several migration outcome variables at the prefecture-level: migration outflows, migration inflows, and the number of total residences in each prefecture. Though the migration history information is in detail, we do not the intermediate location in some cases, for example, if an individual leaves the hukou place in 2011-2013 and migrates to a place different from the residence in 2014 and 2015. As a robustness check, we exploit the fact that there are fewer measurement errors in individual place of residence for the years 2010, 2014, and 2015 to ensure our findings are not affected by the lack of information on step migration and return migration.

Air Quality Data We use satellite measure of air quality since reliable ground-based pollution data are only available after the monitor installation. We choose the yearly $PM_{2.5}$ from Atmospheric Composition Analyis Group (0.01×0.01 degree), a more sophisticated measure constructed based on GEOS-Chem chemical transport model and AOD from multiple satellite instruments including NASA MODIS, MISR, and SeaWIFS (Van Donkelaar, Martin and Park, 2006; Hammer et al., 2020).[3] AOD serves as a proxy for air pollution because it captures the

[3] The $PM_{2.5}$ satellite data can be found from this link. Satellite measure of air pollution are shown by the literature to be a good approximation of ground-level air pollution. We provide scatter plots in Figure A.3 to validate the satellite-based air pollution data that we use.

concentration of various aerosol particles through the degree that sunlight is absorbed or scattered before reaching the ground. These particles include sulfates, nitrates, micro particulate smaller than 2.5 micrometers (PM2.5) and smaller than 10 micrometers (PM_{10}), dust, sea salts, and other particles.

We favor the PM2.5 data for several reasons. First, it has finer resolution and fewer missing values. Second, PM2.5 is one of the most salient indicators of regional pollution for the public and local governments in the period of interest. This is because PM2.5 is one of the main pollutants, and being able to measure the concentration of PM2.5 is one of the crucial features of the new monitors. Third, it is closer to the air pollution level on the ground, since dust and sea-salt are removed and the model is calibrated to match ground-based air quality measures from a credible third-party.[4] The interpretation is also easier and more direct. We use the two-year average of PM2.5 in 2010-2011 to measure initial regional pollution before the program announcement. Using the two-year average reduces the contamination of unknown shocks.

Local Leader Characteristics To disentangle the migration response through the environmental regulation mechanism, we exploit the variation in mayors' promotion incentives as a proxy for regulation intensity. The information on the characteristics of mayors and city party secretaries is from the database compiled by Jiang (2018). The database has extensive demographic and career information of over 4,000 key city, provincial and national leaders in China since late 1990s, including the information on all city party secretaries and mayors between 2000 to 2015.

The promotion incentives of secretaries and mayors are restricted by age. The age upper bound of promoting one at bureau-director level (secretaries and mayors in most prefectures) to sub-provincial level is 57, that of promoting one at sub-provincial level (secretaries and mayors in fifteen big prefectures) to provincial-ministerial level is 62, and that of promoting one at provincial-ministerial level (secretaries and mayors in four municipalities) to sub-national level is 66. We use the database to calculate the age of the local leaders at the National People's Congress (NPC), March 2013 and March 2018, to determine the yearly promotion incentives in 2011-2015.

Descriptive statistics Table C.1 summarizes the sample size, mean, standard deviation, frequency, and time span of the data used in the empirical analysis.

[4] Thus regions like Xinjiang where the PM2.5 level is high due to dust instead have more moderate values of PM2.5.

Table C.1: Summary statistics

Variable	Obs.	Mean	Std. dev.	Time span	Freq.
Prefecture-level data					
Number of residents in census	1,685	5303.86	(3926.57)	2011-2015	Yearly
% of residents leaving the pref.	1,685	2.18	(2.78)	2011-2015	Yearly
% of residents moving within the pref.	1,685	0.63	(0.61)	2011-2015	Yearly
% of residents entering the pref.	1,685	1.34	(1.99)	2011-2015	Yearly
Initial PM2.5 in 2010-2011	337	58.18	(22.87)	2010-2011	Two-year
Promotion dummy of mayor	1,680	0.87	(0.34)	2011-2015	Yearly
Promotion dummy of party secretary	1,680	0.67	(0.47)	2011-2015	Yearly

3.4 Migration Responses to Pollution Information

In this section, we first introduce the empirical strategy, then investigate the average program impact on migration outcomes, and finally provide evidences of mechanisms. Our empirical strategy relies on the information shocks created by the roll-out of pollution information disclosure program and heterogeneity in regional pollution before the program. The parallel trends assumption is supported by event studies using our specification.

We extend the literature on air pollution and migration by highlighting the importance of pollution information in migration decisions. We show a substantial increase in migration outflows from polluted prefectures due to the pollution information disclosure. However, the decrease in migration inflows is of a smaller magnitude and insignificant. The program impact differs across age groups and between rural/urban areas.

We consider two mechanisms in explaining the program impact. One is the improved perception of pollution-induced health cost, which has been used to explain the drop in mortality after the program by Barwick et al. (2020). The other is the rising environmental regulations, a new and important mechanism relative to the literature. Since the findings of average program impact can be rationalized by either mechanism, we conduct two analyses to validate the mechanisms. First, to check whether people migrate away to avoid pollution-induced health cost, we use bilateral migration flows to test whether people living in more polluted prefectures show a higher tendency to move to cleaner places after the program. Second, to check whether people migrate away due to rising environmental regulations, we check whether prefectures where mayors have higher incentives of pollution abatement after the program observe a larger migration outflows given pollution levels.

3.4.1 Empirical Strategy

We use a extended difference-in-differences specification to provide estimates of the magnitude of the effect. Formally, we estimate:

$$Y_{it} = \beta_0 + \beta_1 \times Pollution_i \times Post_{it} + \phi_i + \phi_{wt} + \phi_p t + \varepsilon_{it}, \tag{3.1}$$

where Y_{it} is the aggregate migration outcomes of prefecture i at year t. Though we have individual yearly residence place at the county level, we aggregate migration outcomes to prefecture instead of county level to avoid the bias due to extreme values of small counties. $Post_{it}$ is the indicator of whether air quality monitors have been installed in prefecture i at year t. Initial pollution level $Pollution_i$ is the log of yearly average $PM2.5$ of prefecture i at 2011. ϕ_i is prefecture fixed effect controlling regional persistent unobserved heterogeneity in population, $\phi_p t$ controls heterogeneous province-specific time trends, and ϕ_{wt} is wave by year fixed effects controlling time-varying trends that differ across prefectures in different waves. Wave by year fixed effects, which makes sure the comparison across cities in the same wave, is critical for our identification as location, size, and environmental regulations are quite different in different waves (Axbard and Deng, 2020).

3.4.2 Average program impact

Since migration is a bilateral flow from origins to destinations, we want to figure out whether the program takes an effect through origins or destinations and through short-distance or long-distance moving. Thus, we pick four core outcomes: log of total residence, percentage of residents moving out of prefectures, percentage of residents moving between counties within prefectures, and percentage of new residents. Using log of total residence is equivalent to using population share to examine the net change in geographical population distribution. Table D.2 presents the effect of information disclosure from separate estimations of the four core outcomes using Equation 3.1. The point estimates represent the average estimated impact of information disclosure on migration outcomes when initial pollution increases by 1%.

Table D.2 implies that, if the initial pollution increases by 1%, the prefecture-level population would decrease by 0.038% and the migration outflow across prefectures would increase by 0.028%. These magnitudes are not small given that the average yearly PM2.5 in China increased from $60.7 ug/m^3$ in 2000 to $70.5 ug/m^3$ in 2011, i.e. about 16%.[5] However, the change in the share of new comers among all the residents is small and insignificant. There are two potential explanations. First, people pay more attention to the air pollution problem when they are

[5] World Bank data: link

experiencing it. Second, when people leave polluted prefectures because of rising environmental regulations, they do not necessarily migrate to clean areas. Another important finding is that the program mainly affects migration across prefectures but not that within prefectures. One explanation is the small difference in pollution level within prefectures given the similarity in industry structure. The second explanation is that we are unable to observe temporary changes, such as commuting decisions.

Table D.2: Average program impact on migration outcomes

Outcome	(1) Log(Population)	(2) Out-migration rate Across pref.	(3) Out-migration rate within pref.	(4) New comer share
Post × log(PM2.5)	-0.038***	2.76***	0.14**	0.040
	(0.0054)	(0.32)	(0.060)	(0.11)
R2 Adjusted	1.00	0.75	0.71	0.88
Observations	1685	1685	1685	1685

Notes: Each observation is a prefecture-year pair computed using Population Census 2015. The data cover 377 prefectures in 2011-2015. The log(PM2.5) is average PM2.5 concentration in 2010-2011, measuring regional initial pollution before the information program. The coefficient captures the average estimated impact of information disclosure on migration outcomes when initial PM2.5 increases by 1%. Prefecture FE, wave-year FE, and differential trends by province are controlled. Standard errors are clustered at the prefecture level.

Parallel trends assumption The DiD approach requires parallel trends in migration outcomes between prefectures with different pollution levels prior to the information disclosure. To test this assumption, we estimate a dynamic model based on the event study framework.[6] Since the frequency of our data is at yearly level, we define the events at the same level. Controlling for leads allows us to examine the pre-disclosure effects as a test for the parallel trends, and helps disentangle anticipatory effects. The lags allow for the time varying treatment effects relative to the average effect in Equation 3.1.

We use the same outcome variables as in Table D.2 except for share of new comers. Figure D.1 shows the coefficient estimates of $Pollution_i^k$, the interactions between event dummies and initial pollution level. These estimates measure the difference in migration outcomes k years relative to the information program when initial PM2.5 increases by 1%. The baseline (k=0) corresponds to the year just before the start of information disclosure (the dashed vertical line). Each dot is an estimate of relative time parameter in Equation 3.2 for the given year. The bars extending from

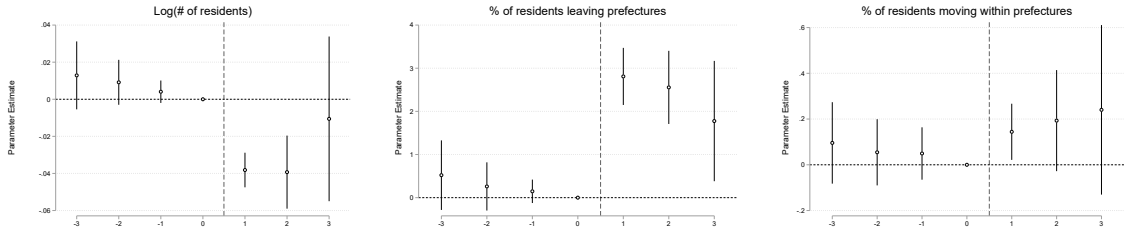
[6] Specifically, we include leads and lags of the information disclosure dummy:

$$y_{it} = \beta_0 + \sum_{-3<k<3} \gamma_k \times Pollution_i^k + \phi_i + \theta_{wt} + \phi_p t + \varepsilon_{it}, \tag{3.2}$$

where $Pollution_i^k = Pollution_i \times \mathbb{1}\{t = k\}$, jointly represent the interaction between information disclosure events and initial pollution $Pollution_i$ (the log of yearly average $PM2.5$ of prefecture i at 2010-2011).

each point show the bounds of the 95% confidence intervals.

Figure D.1: Event Study of Average Program Impact



(a) Log(pop) (b) Out-mig. across pref. (c) Out-mig. within pref.

Notes: This figure shows the coefficients of $Pollution_i^k$, where k is the relative time with respect to the year of monitor installation. The dependent variables are the log of total residents, the percentage of residents leaving the prefectures, and the percentage of residents moving within prefectures of the year. These variables are computed from Population Census 2015. Each observation is a prefecture-year pair. Prefecture FE, wave-year FE and Provincial time trends are controlled. Standard errors are clustered at the prefecture level.

In Figure D.1, the estimated coefficients of the leads ($k < 0$) are small in magnitude relative to those of the lags ($k \geq 1$) and statistically indistinguishable from zero. Hence, there is no evidence of meaningfully differential trends in aggregate migration outcomes across prefectures with different initial air pollution levels before the program. Also note that although the magnitudes of the lags are similar to those in Table D.2, they decrease over time when the dependent variables are log of total residence and out-migration share. There are two potential reasons. First, it takes time for individuals to migrate away and the economy reaches a new equilibrium after three years. Second, the variable $Pollution_i^3$ is only relevant for prefectures in the first wave (2013). Thus, $Pollution_i^3$ has less variation (large standard errors) and smaller magnitudes (see Figure A.2) than $Pollution_i^1$ and $Pollution_i^2$.

Heterogeneity in impact To understand whose migration decisions are affected by the program, we rerun the regression of Equation 3.1 for sub-populations and focus on the outcome variable log of total residence. The estimates of population change due to the program when initial prefecture-level PM2.5 increases by 1% are in Table D.3.

The results imply that the information program has the largest impact on migration decisions of the young people (aged 21-40) compared to other age groups. There are two potential reasons. First, young people are familiar with digital technology and the air pollution information mainly spreads through online news and mobile apps.

Second, young people are the most mobile. The magnitudes of "Post x log(PM2.5)" are similar between people with less than high school education and those equal or above, but the coefficient of the former is strongly significant. There are two potential explanations. On the one hand, people with low education are more involved in outdoor activities in employment. On

Table D.3: Estimation of Program Impact on the Number of Residents by Sub-population

	(1)	(2)	(3)	(4)
Dependent variable:		Log(Number of residents)		
Subdivision:	age 6-20	age 21-40	age 41-60	age 61-80
Post × log(PM2.5)	-0.016***	-0.077***	-0.034***	-0.0072***
	(0.0048)	(0.010)	(0.0048)	(0.0016)
Observations	1685	1685	1685	1685
	(5)	(6)	(7)	(8)
Dependent variable:		Log(Number of residents)		
Subdivision:	$\leq$ middle school	$\geq$ high school	outside city	city center
Post × log(PM2.5)	-0.039***	-0.033*	-0.052***	-0.027***
	(0.0055)	(0.018)	(0.0066)	(0.0061)
Observations	1685	1685	1535	1650

Notes: Each observation is a prefecture-year pair in 2011-2015. The log(PM2.5) are prefecture average PM2.5 concentration in years 2010-2011. Prefecture FE, wave-year FE, and differential trends by province are controlled. Standard errors are clustered at the prefecture level. The "city center" in column (6) refers to districts in city center and city-level counties, while the "outside city" in columns (5) refers to all the counties except city-level counties.

the other hand, low-skilled workers are more affected by environmental regulations on pollution emission, since technology upgrading requires high-skilled workers.

Columns (7)-(8) indicate that though monitors usually locate in city centers, the magnitude of the program impact is greater for counties than for cities and city-level counties.[7] From the perception perspective, monitors in cities can still raise individual awareness of air pollution problem in counties through words spreading and extrapolation. From the regulation perspective, one third of industrial firms are located in counties, and the rising environmental regulations are not restricted to areas close to monitors. It makes sense for us to observe a greater increase in out-migration rate in counties than in cities when the information program incurs similar utility drops, because the loss of leaving cities is greater.

Mechanisms The above results are in line with our expectation that the information program substantially affects individual migration responses to air pollution problems. But the heterogeneity in program impact across sub-populations can be rationalized by both mechanisms that we have in mind. The first mechanism is that the information program increases individual awareness of the severity of air pollution problems at where they leave and want to go through mobile apps, news, and words spreading. As a result, people better internalize the pollution-induced health cost in their migration decisions. The second mechanism is that the information program helps and also pushes both the central government and local government to monitor regional air pollution level and regulate the pollution emission of industrial firms.

In the appendix, using the same or similar DiD strategy as in Equation 3.1, we show in Table C.2 that given certain air pollution level, the information program make people think the

[7] We find increases migration flows both from counties to city centers and from city centers to counties.

neighboring air pollution problem is more severe than what they thought before, and search more about related keywords such as "air pollution", "haze/smog", "PM2.5", and "air mask". Given certain air pollution level, the information program also increases the number of environmental enforcement on firms for air pollution emission (Table D.3) and the individual probability of being unemployed (Table D.4). The magnitudes of those changes in different prefectures increase with the level of initial air pollution problem before the program.

To provide further support for the two mechanisms, we proceed by checking whether people indeed migrate away from polluted prefectures for cleaner ones due to the program and whether the resulting changes in environmental regulations affect individual migration decisions.

Moving to cleaner prefectures In this part, we explore whether individuals living in more polluted prefectures have a higher tendency to move to cleaner ones due to the information program. Specifically, we use the level of yearly bilateral migration flow between prefectures as the dependent variable and estimate the following specification using Poisson pseudo-maximum likelihood (PPML):[8]

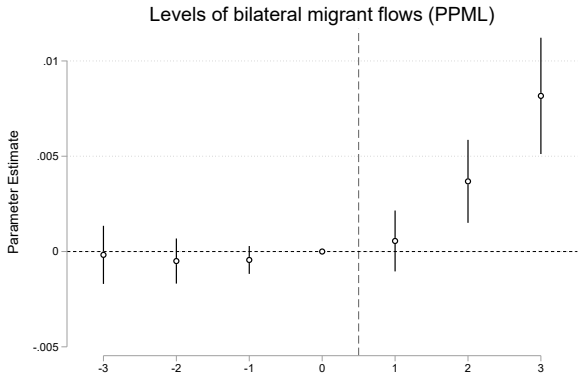
$$MigFlow_{ijt} = \beta_0 + \sum_{-3<k<3} \gamma_k \times Pollution_i^k \times Cleaner_{ij} + \phi_{it} + \theta_{w_i w_j t} + \phi_{ij} + \varepsilon_{ijt}, \qquad (3.3)$$

where $MigFlow_{ijt}$ is the level of migration flow from prefecture i to prefecture j in year t, $Pollution_i^k = Pollution_i \times \mathbb{1}\{t = k\}$ represent the interaction between information disclosure events and initial pollution $Pollution_i$ (same as in equation (3.2)), $Cleaner_{ij}$ is a dummy which equals one if the initial pollution of prefecture i is higher than that of prefecture j, ϕ_{it} is origin-time fixed effect (to control for multilateral resistance to migration, origin-specific number of potential migrants, and the difference in out-migration rate by origin due to the information program), ϕ_{ij} is prefecture-pair fixed effect, and $\theta_{w_i w_j t}$ controls for wave-wave-year FE (similar to that in equation (3.2) but here is the interaction between origins and destinations).

Figure D.2 shows the coefficient estimates of $Pollution_i^k \times Cleaner_{ij}$. These estimates measure the change in migration flows to cleaner prefectures after the information program versus before when initial PM2.5 increases by 1%. Exploiting event study allows us to check pre-trends and examine the program impact at the same time. The coefficients for $k = -1, -2, -3$ support our assumption that the variables $Pollution_i^k \times Cleaner_{ij}$ only pick the impact driven by the information program rather than other pre-existing unobserved heterogeneity. The coefficients for $k = 1, 2, 3$ indicate an interesting pattern that the individual migration to avoid air pollution takes time to realize. This is in line with the fact that migration as a long-term decision usually

[8] This specification can be rationalized by pseudo-gravity migration model derived from a random utility maximization model (Beine et al., 2014). The advantage of using PPML is to mitigate the information loss when there are many zeros in migration flow.

Figure D.2: Event Study of bilateral migration flow



Notes: This figure shows the coefficients of $Pollution_i^k \times Cleaner_{ij}$, where k is the relative time with respect to the year of monitor installation. The dependent variable is the level of bilateral migration flow from prefecture i to prefecture j in year t. Each dot is an estimate of relative time parameter in Equation 3.3 for the given year. The bars extending from each point show the bounds of the 95% confidence intervals. The baseline corresponds to the year before the program, and the dashed vertical line marks the opening of information disclosure. Origin-year FE, origin-destination FE and wave-wave-year FE are controlled. Standard errors are clustered at the origin-destination level.

takes time to make the plan and realize. The immediate increase in out-migration rate in Figure D.1 implies the relevance of other mechanisms that could make individuals to migrate within a year.

Evidence on Regulation Mechanism The regulation mechanism is the alternative that is consistent with an immediate increase in out-migration rate due to the program. Facing increasing environmental regulations on pollution emission through fines and production suspension, some firms exit the market or adjust worker employment for technology upgrading in production and pollutant processing before emission. As a result, Some people would lose their jobs and migrate away for earnings.

To show that the rising environmental regulations due to the program indeed affects individual migration decisions, we exploit the variation in promotion incentives of mayors. The reasoning is as follows. The information program leads to an increase in environmental regulations for various reasons. One of them is the pressure from the central government towards local governments on air pollution abatement through promotion competition between local leaders. With the new air quality monitors, the local governments face the checks from the central government and the risk of having local air pollution problems widely discussed or criticized by the public in social media. We assume mayors with promotion potentials face higher pressure on air pollution abatement than those without. Thus, following Axbard and Deng (2020), we exploit the promotion age restriction to examine whether we observe a greater increase of out-migration rate in prefectures

where mayors have promotion incentives than those where mayors will not be promoted any further.

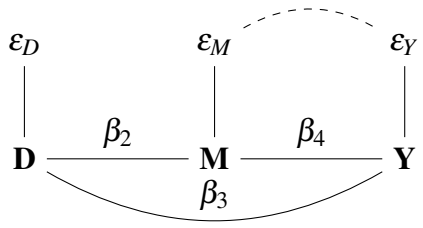
As explained in section 47, the promotion of mayors is restricted by age, and the age cutoff varies by the administrative levels of prefectures. Panel B of Table D.4 presents the regressions of interest. Specifically, we construct a promotion dummy for mayors of each prefecture in 2011-2015 and interact it with "Post×log(PM2.5)". The value of the promotion dummy equals one if the mayor is eligible for promotion in the next National People's Congress (every five years). The coefficients of "Post×log(PM2.5)×Promotion" are significant and negative, indicating that the environmental regulation mechanism goes in the same direction as the health cost perception mechanism.

We also conduct three robustness checks. First, Panel A checks whether there is an intrinsic correlation between the treatment variable of interest and the promotion incentives and gender of mayors. We do not find any meaningful correlations. Second, columns (3) and (4) in Panel B present the results of regressions after excluding the regions involved in "Action Plan on Air Pollution Prevention and Control" as in Table B.1. Again, the coefficients do not change much. Third, in Panel C, as a placebo test, we construct a promotion dummy for party secretaries using the same strategy since mayors rather than party secretaries are responsible for pollution abatement. The results are in Table D.4. Similar to our expectation, the coefficients are insignificant when the promotion dummy is based on the ages of party secretaries.

3.5 Unpacking the Effects of Information Disclosure

In previous sections, we show that the regulation mechanism is one of the channels behind the migration responses that we observed in the data. In this section, we go further and apply mediation analysis to quantify the relative importance of the labor-market mechanism.

Figure E.3: Mediation Model



The simple mediation model to assess the causal mechanisms behind the effect of information on migration is illustrated in Figure E.3. The mediation model consists of a treatment variable D (in our case, an information shock), a final outcome Y (in our case, migration decision), and a

Table D.4: Promotion Incentive

	(1)	(2)	(3)	(4)
Panel A: Selection of mayors and party secretaries				
Outcome	Promotion incentive		Being a female	
	Mayor	Party secre.	Mayor	Party secre.
Post×log(PM2.5)	0.012	-0.014	-0.034	0.00022
	(0.048)	(0.064)	(0.032)	(0.031)
Observations	1680	1680	1680	1680
Panel B: Promotion incentives of mayors				
Outcome	Log(Pop.)	Out-mig. rate Across pref.	Log(Pop.)	Out-mig. rate Across pref.
Post×log(PM2.5)	-0.033***	2.42***	-0.034***	2.41***
	(0.0059)	(0.33)	(0.0054)	(0.34)
Post×log(PM2.5) × Promotion	-0.0037**	0.24***	-0.0037***	0.22***
	(0.0015)	(0.074)	(0.0013)	(0.082)
Promotion	0.0018	-0.35***	0.0030	-0.34**
	(0.0035)	(0.14)	(0.0027)	(0.14)
Observations	1680	1680	1505	1505
Panel C: Promotion incentives of party secretaries				
Outcome	Log(Population)	Out-migration Across pref.	Log(Population)	Out-migration Across pref.
Post×log(PM2.5)	-0.038***	2.75***	-0.039***	2.73***
	(0.0055)	(0.32)	(0.0052)	(0.33)
Post×log(PM2.5) × Promotion	-0.0015	0.0055	-0.00060	-0.0046
	(0.0014)	(0.070)	(0.0012)	(0.080)
Promotion	0.0032	-0.22*	0.0048**	-0.24*
	(0.0028)	(0.12)	(0.0023)	(0.13)
Observations	1680	1680	1505	1505

Notes: This table supports the relevance of regulation mechanism. Mayors rather than party secretaries are responsible for pollution abatement. Panel A shows no meaningful correlation between characteristics of local leaders and the treatment variable of interest. Panel B and C are extensions of Table B.1, where we focus on log of population and percentage of residents leaving prefectures as dependent variables. Columns (1)-(2) include 337 prefectures, while columns (3)-(4) excludes the prefectures involved in "Action Plan on Air Pollution Prevention and Control". Here we include the promotion dummy defined by promotion age limit and the interaction between the promotion dummy and "Post×log(PM2.5)". The aim is to disentangle the program impact through the environmental regulation mechanism. Panel C serves as placebo tests for Panel B. The log(PM2.5) is average PM2.5 concentration in 2010-2011. Prefecture FE, wave-year FE, and differential trends by province are controlled. Standard errors are clustered at the prefecture level.

mediating variable M (in our case, measures of regulation tightness) that represents a mechanism through which D affects Y. The mediating variable M itself is causally affected by T, and mediates part of the total causal effect of D on Y. Essentially, the model decomposes the 'total effect' (TE) of D on Y - that is, the effect we have already identified in previous section - into a

'direct effect' (DE), and an 'indirect effect' (IE) running through M. In our mediation analysis, the direct effect of D on Y that is independent of M is given by the coefficient. The indirect effect running through M is given by the coefficient multiplication Y. Our focus is on this mechanism. The total effect can be evaluated by the sum of these two terms.

In our setup, the effect of tightness of regulation on migration response, is straightforward to estimate the following equation:

$$Y_{it} = \beta_0 + \beta_3 D_{it} + \beta_4 M_{it} + \phi_i + \psi_{wt} + \chi_{it} + \varepsilon_{it},$$

where D_{it} is short for $Pollution_i \times Post_{it}$. Y_{it} is the main outcome variable, migration rate. M_{it} is the mediating variable, a measure of the tightness of the regulation. Similar to the baseline DiD model, we control for ϕ_i, ψ_{wt}, and χ_{it}. To consistently estimate β_1 and β_2, we follow ■ and use the instrumental variable approach. The construction of the instrumental variable is motivated by the previous analysis which enforcement responses are stronger when the mayor more motivated. Hence, the instrumental variable is the interact D with Z, whether mayor is motivated.

Theoretically, several variables could qualify as a mediator, such as unemployment rate, total enforcement, and AOD. However, in practice, only two variables (i.e., enforcement and AOD) are eligible due to the data availability between 2011 and 2015, the main sample period.[9] Our empirical approach allows one to identify the mediating effect of one M only. Following Dippel et al. (2021), we aggregate these two variables into principal components and focus on the mediating effects of the tightness if regulating M in the aggregate.

To decompose the total effect of D on Y into the direct effect of D on Y and D's indirect effect through M, we implement the mediation model. Specifically, we estimate the two-stage model described in equation 3.5. Our focus is on the extent to which the effect of information on migration (reported in Table D.2) works through the effect of information on tightness of the regulation. The results are reported in Table E.5. The coefficient β_4 reports the causal effect of the tightness of the regulation M on migration Y. The point estimate indicates that a 1% drop in the tightness of the regulation increases out migration by percentage points. Relating this to the estimated total effect of D on Y, reported in Table D.2, suggests that the IE is around 30% of the TE. D's direct effect increases by migration by . Note that β_3 and $\beta_2 \times \beta_4$ add up to the total effect (β_1) of 0.024 estimated in Table D.2, i.e., $DE + IE = TE$.

The indirect effect running through the regulation channel explains around 30%, which means that the migration response to information disclosure would have been even weaker if regulation were not affected. In summary, our results clearly show that the labor market responses to information that has been ignored in the literature so far contribute substantially to the migration

[9] Measurements of the Labor market condition would be one good candidate for the mediator. However, there is no representative unemployment rate information at the city level.

Table E.5: Estimates of the Mediation Analysis

Outcome	(1) Out-migration rate	(2) Log(Population)
Panel A: estimates from equation 3.5		
Post×log(PM2.5) (β_3)	1.71***	-0.025***
	(0.37)	(0.0058)
Regulation Tightness (β_4)	2.42***	-0.035***
	(0.64)	(0.013)
Observations	1680	1680
Panel B: parameters of the mediation model		
1st stage (β_2)	0.37	0.37
IE ($\beta_2 \times \beta_4$)	0.89	-0.013
DE (β_3)	1.71	-0.025
TE (β_1)	2.60	-0.038
IE/TE	0.34	0.34
F-stat of the 1st stage	91.58	91.58

Notes: The table presents second-stage results from estimating the mediation models. Panel B summarises related model parameters and explains how they can be assessed. All specifications include the full set of control variables as in Table 1.

response.

Discussion In this part, we would like to discuss about the welfare implications of information programs based on our findings. Merely considering the perception mechanism, we would easily conclude that information programs bring welfare gains. However, the regulation mechanism implies that a substantial number of individuals suffer from the rising environmental regulations and migrate away for employment concerns, even though the resulting drop in regional air pollution would improve the utility of stayers. Compensations could be considered to make up the losses of individuals sacrificing for environmental protection.

Furthermore, it is important to note that mobility constraints restrict individual capability of migrating away either for health considerations or for economic losses. For example, although elders are sensitive to air pollution, it is difficult for them to migrate away from where they have settled down. Although air pollution problems are severe and the regulations are tight in cities, many people choose to stay due to the lack of good outside options.

3.6 Conclusion

This paper contributes to the literature by highlighting the role of pollution information in individual protective migration responses to air pollution. To our best knowledge, this is also the

first study that points out the relevance of and quantifies the unintended information impact on individual migration decisions through rising environmental regulations.

Specifically, we exploits the roll-out of a nationwide air quality monitor installation in 2013-2015 in China to study the impact of pollution information disclosure on individual migration responses to regional air pollution. Using individual yearly county/district-level location information in 2010-2015 from 1% Population Census 2015, we examine the change at the prefecture level. We show that when the concentration of PM2.5 increases by 1%, the prefecture-level population decreases by 0.038% and the out-migration rate increases by 0.028% on average due to the program. This is a reasonable but big estimate for air pollution-induced migration responses because the increase of PM2.5 concentration is substantial for China, 16.5% from 2000 to 2010. The heterogeneity in impact is large across different age groups, a big impact on young people and a very small impact on elders. But the heterogeneity across people with different education levels is small.

We consider two mechanisms to explain the program impact on individual migration responses to air pollution. The first is the improved perception of pollution-induced health cost. Indeed we find that people living in more polluted prefectures have a higher tendency to move to cleaner prefectures after the program. The second is the rising environmental regulations, and indeed we show that prefectures where mayors have higher promotion pressure on pollution abatement observe a greater increase in out-migration rate after the program. With mediation analysis, we show that the environmental regulations accounts for at least 30% of the total program impact. Neglecting the regulation mechanism, we would overestimate individual willingness to pay for clean air to a large extent.

This paper also has several limitations. First, although the individual location information is at the county level, we conduct the analysis at the prefecture level to avoid the bias of extreme values of small counties due to the limited sample size. This choice prevents us from exploiting the heterogeneity in air pollution within prefectures and examining more heterogeneity in migration responses. Second, although the Population Census 2015 provides rich information on migration history compared to previous censuses in China, we are unable to document changes in short-term adjustments such as commuting decisions. Third, we lack credible firm-level data to check the impact of the information program on technology upgrading, pollutant processing, and employment. Finally, we lack an instrument for perception improvement to precisely quantify the effect of the health cost perception mechanism.

There are several potential extensions for the future research. First, a welfare examination of information programs taking into account unequal distribution of employment impact and adjustment constraints would be helpful. Second, it is also worthwhile to conduct similar investigations in other developing countries suffering air or other types of pollution problems.

Appendix 3.A Correlation between initial pollution level and changes in migration measures

Figure A.2 is the scatter-plot of initial pollution and the changes of population and migration outflow after the program by wave using the census. The percentage change is calculated using aggregate measures in 2010-2011 and 2015. Migration outflow is measured by out-migration rate, i.e. the share of residents leaving the county/district in that year conditional on living there in the previous year. For prefectures in each wave, higher level of air pollution is negatively correlated with population change and positively with out-migration rate change. The prefectures in different waves have different magnitude of changes.

Figure A.1: The Staggered Introduction of New Monitors

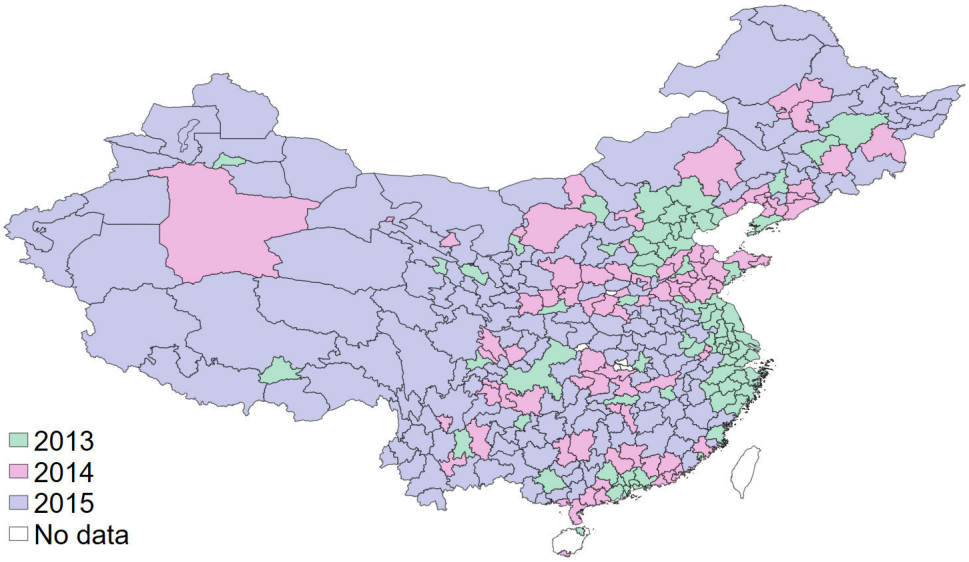
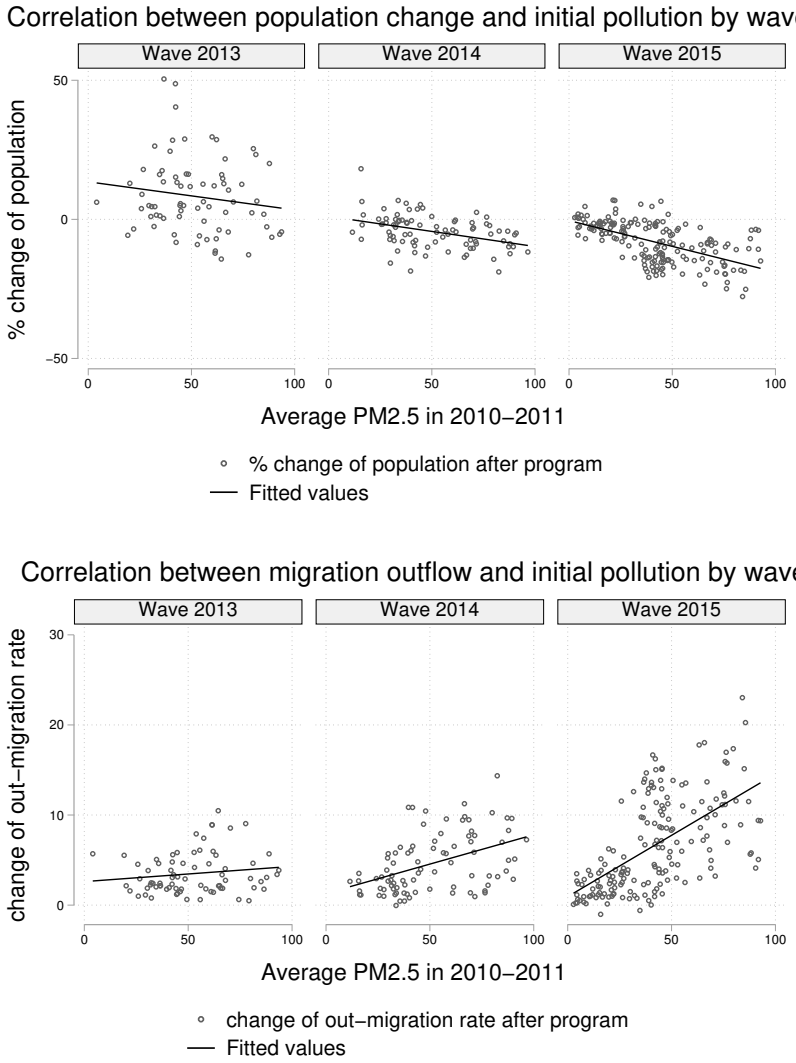
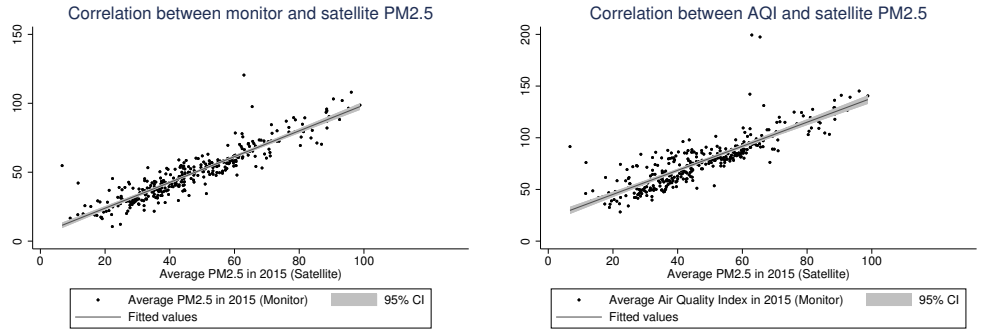


Figure A.2: Correlation between initial pollution and changes in migration measures



3.A.1 Validation of satellite-based air pollution measure

Figure A.3: Scatterplot of ground-level air pollution and satellite measures



(a) Ground-level PM2.5 (b) Air Quality Index

Notes: This figure shows the relationship between ground-level air pollution measures provided by the new air quality monitors and satellite-based pollution. Each dot corresponds to prefecture-level air pollution in 2015. The solid line corresponds to the fitted value of a simple linear regression of ground-based measures over satellite-based ones. Shaded region shows the 95% confidence interval. We pick two ground-level measures: PM2.5 (a) and Air Quality Index (b, a comprehensive measure based on multiple pollutants.)

Appendix 3.B Robustness Checks of Program Impact

Step and Return Migration As the discussion in Section 3.3, we combine two pieces of information to construct the migration flow matrix: place of registration, and place of residence; the main reason for leaving their place of registration, which year they left, and their place of residence one and five years before the interview. The advantage of working with this data is that they are representative of the whole population. However, the advantage comes with a cost, i.e., not all migration spells are observed. Two types of migration spells are missing in our construction: step and return migration. Step migration occurs when migrants transit through another city before reaching their destination. Return migration occurs when migrants leave their places of registration after 2010 but come back before 2015 so that they do not appear as migrants in the Mini-Census.

The richness of information in the 2015 Mini-Census gives us better control over step migration and return migration spells. Unlike the previous version of Mini-Census, our data records both the timing of departure from a migrant's place of registration and the timing of arrival at destination.[10] We can estimate how many migrants move to a third-place before moving

[10] In 2005 Mini-Census, the date of departure from the place of registration differs from the date of arrival at the current destination. Therefore, previous studies (Imbert et al., 2021) use the date of departure as a proxy of the date of arrival, which amplifies the problem of step migration.

to the current city, a measure of the step migration. Another way to detect using reported different destinations between 2010 and 2015 would be a proxy for step migration. Using both approaches, we find the fraction of step migration is around 2%.

On the contrary, past studies tend to find that return migration generates larger measurement errors when constructing migration flows from Census data. To shed more light on this issue, we first identify total return migration between 2011 and 2015, and 2014 and 2015. Then, among all migrants who were living in their cities of registration in 2011 and in other cities in 2014, we compute the fraction that had returned to their cities of registration by 2015. This share is not negligible. In a given year, around 4% of rural migrants who had left their provinces of registration in the last five years go back to their hukou locations.

To further make sure that the missing part of return migration is not going to bias our finding. We restrict the sample to the number of residents in the years 2010, 2014, and 2015, in which we know individual exact residence place. This restricted sample don't suffer the measurement error caused by either step or return migration. At the same time, the flow variables are also less affected from the step or return migration when the location of residence is precise. Thus, we also include the outcomes of migration outflow and inflow in the years 2011, 2014, and 2015. The estimates using the same model with these restricted sample periods are presented in Panel A of Table B.1. We can notice that the estimates with the new sample are similar to the main results though slightly greater in magnitude, which provides reassurance that our estimates capture the effect of information disclosure on migration.

Confounding Environmental Policies Following Wang and Zhang (2021), one concern is the "Action Plan on Air Pollution Prevention and Control" implemented in September 2013, may confound the effect of information disclosure. It requires the cities in Beijing-Tianjin-Hebei region, Yangtze River Delta, and Pearl River Delta to reduce the concentration of air pollutants by technology upgrading, pollutant processing, and changing energy structure. This policy has an ambiguous bias on the estimation of information program impact. On one hand, expecting a big drop of air pollution problems in these cities in the long run, people are willing to wait rather than migrate away. On the other hand, these cities will spend more efforts on the regulation of firms' air pollutant emission and generate greater employment losses. After all, these cities are economically more developed than other cities in China and could demonstrate different migration responses. Thus, we exclude the cities affected by this action plan and re-estimate the baseline model. The corresponding results, shown in Panel B of Table B.1, are similar to those from the baseline model.

Table B.1: Sensitivity Analysis

Outcome	(1) Log(Population)	(2) Out-migration rate Across pref.	(3) Out-migration rate within pref.	(4) New comer share
Panel A:				
Post × log(PM2.5)	-0.046***	3.02***	0.20**	0.051
	(0.0066)	(0.35)	(0.077)	(0.11)
R2 Adjusted	1.00	0.72	0.73	0.85
Observations	1011	1011	1011	1011
Panel B:				
Post × log(PM2.5)	-0.039***	2.57***	0.16**	-0.0027
	(0.0051)	(0.31)	(0.062)	(0.11)
R2 Adjusted	1.00	0.75	0.72	0.80
Observations	1510	1510	1510	1510

Notes: This table summarizes the results of two sensitivity analysis. Each observation is a prefecture-year pair computed using Population Census 2015. Panel A covers 377 prefectures in 2011, 2014, and 2015 for migration outflow and inflow and in 2011, 2014, and 2015 for the number of residents. Panel B excludes the observations for prefectures in Beijing-Tianjin-Hebei region, Yangtze River Delta, and Pearl River Delta to reduce the concern about confounding environmental policies such as "Action Plan on Air Pollution Prevention and Control". The log(PM2.5) is average PM2.5 concentration in 2010-2011, measuring regional initial pollution before the information program. The coefficient captures the average estimated impact of information disclosure on migration outcomes when initial PM2.5 increases by 1%. Prefecture FE, wave-year FE, and differential trends by province are controlled. Standard errors are clustered at the prefecture level.

Appendix 3.C Evidence of Perception Change

We use two sources of information to show that the program of pollution data disclosure has increased public awareness: online searches and survey questions.

Online Searches The online search volume data comes from Baidu, the widely used search engine in China. Since 2011, it summarizes the number of queries for specific keywords within a city and day. Like the Google Treads, the Baidu Search Index measures online search intensity, i.e., the total number of searches for the topic relative to all topics, which provides a proxy for public awareness. We focus on the search indexes for "air pollution", "haze/smog" "PM2.5", and "air mask" for people from different prefectures cities in 2011-2015. Slightly different from some early studies, we focus on the yearly index as we are more interested in the long-run impact and the frequency of our migration data set.

Following Barwick et al. (2020), we leverage the search index for over 331 cities in 2011-2015. Using the same DiD strategy as in Equation 3.1, we report the estimates in Panel A of Table C.2 with the mean of the standardized search indexes as the outcomes. The four columns present the results of four keywords correspondingly: air pollution, haze/smog, PM2.5, and Air

mask. The surge in online searches after the information program provides strong evidence that concepts of air pollution and the related adverse health consequences attract public attention due to easy access to related information provided by the program.

Table C.2: Perception

	(1)	(2)	(3)	(4)
Panel A: Online Search indexes				
Keywords	Air pollution	Haze/smog	PM2.5	Air mask
Post × log(PM2.5)	2.49**	7.30*	1.53**	4.03***
	(0.99)	(4.05)	(0.66)	(1.13)
R2 Adjusted	0.94	0.91	0.88	0.95
Observations	1655	1655	1655	1655
Panel B: Survey Questions				
Concerns over	Air pollution	Soil pollution	Water pollution	Noise pollution
Post × log(AOD)	0.218***	0.043	0.128	-0.087
	(0.080)	(0.077)	(0.081)	(0.082)
Observations	15004	15004	15004	15004

Notes: We aim to check whether the public are more awareness of air pollution after the information program using survey questions and online searches. The regressions of Panel A are based on survey questions on pollution perception from CLDS panel data (2014 and 2016). The sample includes all the households recorded in both years. The dependent variable is the household's rating of pollution severity in the neighborhood in a survey year: =1 means not severe at all, =2 means not very severe, =3 means slightly severe, =4 means quite severe. The AOD refers to the monthly Aerosol Optical Depth at the month of the interviews. Individual fixed effect is controlled and the standard errors clustered at the individual level are in parentheses. The regressions of Panel B are based on yearly online search indexes of the five keywords for each prefecture in 2011-2015. Prefecture FE, wave-year FE, and province-specific time trends are controlled. The standard errors are clustered at the prefecture level and reported in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Representative Survey The advantage of using online searches is that the data covers most cities in our primary sample, but online searches can only be thought of as an indirect measure of perception. Thus complement with the representative survey data. The survey questions are taken from China Labor-force Dynamics Survey (CLDS) 2014-2016. It is a national longitudinal data since 2012. In the 2014 and 2016 waves, there are questions asking respondents to rate the severity of air, soil, water, and noise pollution around their homes. The respondents are asked to choose among very severe, slightly severe, not very severe, and not severe at all. We use four to denote "very severe" and one for "not severe at all".

We explore questions on pollution severity in the neighborhood using the baseline regression. We focus on families that responded to pollution perception questions of CLDS in 2014 and 2016 and exploited the time variation in the interview.[11] As the data is an individual-level panel.

[11] 2014 and 2016 are the only waves that have questions over pollution perception.

We control for individual fixed effects instead of city fixed effects in the Equation 3.1.

We use a slightly different specification for survey questions because we have information on the month that households were interviewed. Monthly variation in air pollution helps us to identify the program impact with limited sample size. We use monthly Aerosol Optical Depth (AOD, 0.1×0.1 degree) from Terra and Aqua NASA MODIS.[12] The specification is as follows:

$$\tilde{h}_{ijt} = \alpha + \beta_0 Info_{jt} + \beta_1 AOD_{jt} + \beta_2 AOD_{jt} \times Info_{jt} + \phi_t + \phi_i + \varepsilon_{ijt} \tag{3.4}$$

where $\tilde{h}_{ijt}$ is self-reported perception of severity of each type of pollution of individual i living in prefecture j in year t and is a categorical variable, $Info_{jt}$ is a dummy indicating whether new monitors are installed and used, AOD_{jt} is satellite-measure of air pollution.

The Panel B of Table C.2 shows that after the information disclosure, individuals' perception of the severity of local air pollution increases to a more considerable extent than that without new monitors in more polluted areas. We also conducted placebo tests by looking at the self-reported perceived concerns of other types of pollution, such as water, soil, and noise pollution. As excepted, we find no effect of information disclosure in these placebo exercises.

Appendix 3.D Enforcement of Environmental Regulation

The pubic is not the only consumer of the air quality information. The information disclosure program increases also provides tools to hold local governments accountable for environmental performance. Studies (He, Wang and Zhang, 2020; Axbard and Deng, 2020) find that automated pollution monitor has played a crucial role in enforcing the regulation. Environmental regulations often lead to job loss (Walker, 2013), which can have independent effects on migration decision. It is important to take into account the impact of monitor installation on labor demand through more strict regulations. As we know from the migration literature, economic opportunity is one of the key driving factors in migration decisions. The labor demand channel is very critical for us to understand the migration response to pollution information, which has been largely ignored by the literature.

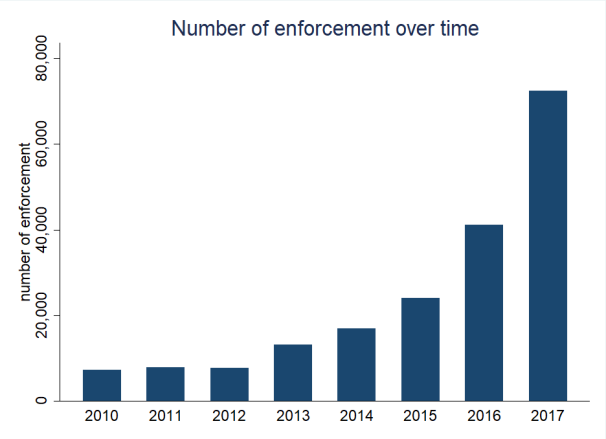
Increase in Enforcement we use firm-level enforcement data from the website of the Institute of Public and Environmental Affairs.[13] If a firm received an official order from the local government indicating its violations of environmental regulations and specifying exact punishment, it is counted as one enforcement. With information on firm location and type of pollution, we compute the yearly number of enforcement at the prefecture level for air pollution as the interest

[12] The *AOD* data is from this link.

[13] The link is http://www.ipe.org.cn/index.html.

and water pollution as the placebo. Figure D.4 depicts the sharp increase in the number of environmental enforcement related to air pollution since 2013.

Figure D.4: Number of air pollution enforcement on firms in 2010-2017



Using the same specification as in Equation 3.1, we first show that the information program has driven up environmental regulation enforcement in cities with high initial air pollution. The results are in Table D.3. Column (1) reports the estimates of enforcement related to air pollution, while column (2) shows the estimate of enforcement on water pollution. We see that if the initial PM2.5 increases by 1%, there are 15 additional air pollution enforcement after the information disclosure on average. As predicted, placebo tests indicate no change in other enforcement for treated cities after the information disclosure.

Table D.3: Enforcement and Air Pollution Convergence

Outcome	(1) # Air enforcement	(2) # Water enforcement	(3) log(AOD)	(4) log(PM2.5)
Post × log(PM2.5)	14.8**	11.9	-0.025***	-0.042***
	(6.05)	(9.78)	(0.0071)	(0.015)
R2 Adjusted	0.85	0.78	0.96	0.97
Observations	1585	1585	1685	1685

Notes: This table presents the regression estimates related to the environmental regulation mechanism. Each observation is a prefecture-year. The dependent variable of columns (1) is the number of any firm enforcement related to air pollution and that of column (2) is for water pollution as a placebo test. Columns (3) and (4) demonstrate the drop of regional air pollution in polluted areas due to the information program. Prefecture FE, wave-year FE, and differential trends by province are controlled for all the regressions. The standard error are clustered at the prefecture level and reported in parentheses.

Evidence from regional pollution After documenting the significant increase in enforcement after the program, we turn the focus to emission reduction to see whether this enforcement effectively reduces the emission. We use the log of AOD and PM2.5 as outcome variables. We

can see from columns (3) and (4) that cities with higher initial pollution experienced a larger drop in AOD and concentration of PM2.5 due to the information program.

Evidence from unemployment The dominant view in the literature is that stricter environmental policy may lead to higher production costs, causing firms to reduce their output and cut back on their inputs, resulting in a decrease in the demand for labor. Firms must either alter their production processes or install pollution abatement equipment to generate less pollution, which may need more or less labor depending on the pollution control strategies of firms. Although the direction in labor demand is ambiguous theoretically, more empirical evidence suggests a decreasing labor demand to more strict environmental regulation. We examine this question using individual data on demographics and employment from Urban Household Survey.

Urban Household Survey (UHS) is a cross-sectional annual survey containing information on demographics and employment of household members and household income and expenditure. We have access to observations in four provinces in 2011-2015: Liaoning, Shanghai, Guangdong, and Sichuan. We focus on the resident population aged 22-54, not in school, and capable of working to examine the impact of information program on the probability of unemployment. Individual characteristics such as gender, education level, age, whether being a migrant, hukou status (rural or urban) are controlled. The UHS survey in 2015 is seasonal, and we convert it to yearly to match the frequency of the other years. The average sample size of 2013-2014 is 181,526, and that of 2011, 2012, and 2015 is 24,243.

We exploit the pollution variation at the county level to make up the small number of prefectures in the data and estimate the following equation:

$$Unemployment_{jt} = \beta_0 + \beta_1 \times log(PM2.5) \times Post_{it} + \phi_i + \phi_{wt} + \phi_p t + \varepsilon_{jt}$$

where j is individual, $Unemployment_{jt}$ is the dummy of being unemployed at year t for individual j, "$log(PM2.5) \times Post_{it}$" is the interaction between the monitor installation dummy and regional initial pollution in 2010-2011, ϕ_i is county fixed effects, ϕ_{wt} is wave-year fixed effects, and $\phi_p t$ is prefecture-specific time trends. Note that UHS is a repeated cross-sectional data and we cannot control individual fixed effects.

From Table D.4, we can observe that individuals in more polluted counties are more likely to be unemployed due to the information program. Here we do not find significant difference in impact between individuals with more than high school education and those below. This is in line with the result of heterogeneity analysis in Table D.3 (columns (5)-(6)). The result in column (3) shows that women are less affected than men. This is consistent with our expectation because females are more concentrated in light industry such as textile and electronics and service industry relative to males and thus less affected by environmental regulations.

Table D.4: Unemployment

	(1)	(2)	(3)
Dependent variable	Dummy of being unemployed		
Post × log(PM2.5)	0.039***	0.038***	0.042***
	(0.013)	(0.013)	(0.013)
Post × log(PM2.5) × AboveHighSchool		0.00065	
		(0.0012)	
Post × log(PM2.5) × Female			-0.0068***
			(0.0015)
R2	0.057	0.057	0.057
Observations	434068	434068	434068

Notes: We examine how information program affects the probability of unemployment using individual data from UHS collected in four provinces. We focus on resident population aged 22-54, not in school, and capable of working. The log(PM2.5) is average PM2.5 concentration in 2010-2011, measuring regional initial pollution before the information program. County FE, wave-year FE, differential trends by prefecture, and individual characteristics such as education level, gender, age, age square, hukou status, and whether registered in other prefectures are controlled. Standard errors are clustered at the county level.

Summary

The thesis study three questions on identity and migration in interacted circumstances. Chapter 1 studies favoritism towards in-group members using cooperative games in natural villages in Yunnan, China. Chapter 2 and Chapter 3 investigate the importance of marriage and health motives in migration decisions and potential biases in policy evaluation due to interacted choices.

In Chapter 1, we ran trust game and public goods game in Yunnan Province in China. In spite of substantial social, economic, linguistic and culture differences,the ethnic groups there are largely harmonious. Consistent with the previous literature, we also found tendencies of favoritism towards co-ethnics but only when other groups are present. This favoritism can bring adverse effects on cooperation especially when group composition is unbalanced. This insight can be applied to corruption where agents corrupt in expectation of lenient punishments from own groups.

In Chapter 2, given that some individuals strategically use marriage to avoid migration restrictions, I develop a dynamic migration and marriage model to study the effectiveness of merit-based migration policies. I first show that individual strategic marriage responses amplify policy impact on migrant inflow but weaken the impact on migrant composition. I apply the model to Chinese data and reforms on hukou registration. Aligned with the theoretical predictions, I show that we would substantially underestimate the migrant inflows to big cities in China if the main migration restrictions (hukou system) would be removed at all.

In Chapter 3, we are interested in the importance of air quality information on individual avoidance behavior-migrating away to avoid air pollution. We exploit the roll-out of an influential national air quality monitor installation program in China and the variation in regional pollution before the program. In addition to an improvement in health risk perception, we show that individual migration responses are also affected by rising environmental regulations through labor demand.

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Contributions of the doctoral candidate in coauthored chapters

Chapter 1: "Favoring your in-group can harm both them and you: ethnicity and public goods provision in China"

Coauthors: César Mantilla, Charlotte Wang, Donghui Yang, and Suping Shen, and Paul Seabright

Published manuscript

Contribution of the doctoral candidate: She was responsible for running the experiment in the field, mainly after recruitment. She was one of main contributors to the econometric analyses together with César Mantilla and Paul Seabright. César Mantilla and she have equally contributed to the project as joint first authors.

Chapter 3: "Revealed Preference or Forced Leave: Migration Response to Pollution Information Disclosure"

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Unpublished manuscript

Contribution of the doctoral candidate: She came up with the research idea and contributed (more than) half to the subsequent econometric analyses and the writing of this chapter.