Essays in Social Economics

Brais Álvarez Pereira

Thesis submitted for assessment with a view to obtaining the degree of Doctor of Economics of the European University Institute

Florence, 21 September 2017

European University Institute
Department of Economics

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Abstract

This thesis consists of three microeconomic essays that depart from the perfectly informed and self-interested agent to analyze important socioeconomic problems which do not find a fully satisfactory explanation under more standard characterizations of individual behavior.

The first chapter explores the role of economic information on housing tenure choice during periods of generalized optimism, such as housing bubbles. A microeconomic theoretical model including biased beliefs about future house prices is developed, and its main predictions tested in the context of the last Spanish housing bubble. The main finding is that better-informed households were less likely than worse-informed ones to purchase their main dwelling in the years leading up to the burst, when houses were highly overvalued.

The second chapter focuses on how the relationship between diversity and performance in hierarchical organizations is mediated by group size. It tests theoretical predictions for individual performance in contexts where knowledge spillovers are important for production, by analyzing the case of Pakistani tax collectors. A legal rule which dictates that 10% of positions must be reserved for members of the army renders this case particularly convenient for observing the effects of diversity.

The third and last chapter proposes a new explanation for the relationship between within-country cultural diversity and support for regionalism —both in the form of demands for more autonomy and outright secessionism. This suggests that other-regarding preferences of individuals might play an important role. We test this relationship using data on electoral support for regionalist parties across ten Western European countries, finding that a region being relatively richer than the country to which it belongs is associated with higher electoral support for regionalist parties only to the extent that it is culturally differentiated.

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Contents

Chapter 1

Heterogeneous Expectations during Housing Bubbles

This chapter develops a microeconomic model of housing tenure choice to explore the distributional effects of biased expectations about future house prices, when these are heterogeneously distributed across the population. An increase in equilibrium prices associated to generalized over-optimism produces an income transfer from the demand to the supply side of the economy. These higher prices imply that better-informed households are less likely to purchase a house than under perfect information, while those that are worse informed are more likely to purchase even at the higher price. I use household data from the years of the last Spanish housing bubble to test this prediction. The combination of generalized optimism and frequent warnings by economic experts and the media about the existence of a bubble should have produced a significant divergence in expectations across Spanish households, with the potential risks being more likely to be understood by the better-informed ones. Using the education level of the head of household as a proxy for individuals' subjective expectations being more closely aligned with the objective distribution, the data shows that, as predicted, households with more years of education were on average significantly less likely to buy a house between 2003 and 2005.

1.1 Introduction

This paper explores the role of biased expectations about future house prices on households' tenure choice and equilibrium prices theoretically, when these biased expectations are heterogeneously distributed across the population. The last Spanish housing bubble is chosen as the case study for the empirical observation of some of the main predictions from the model, given that house prices overvaluation has been particularly high in this country,[1] and that these were a highly salient —and frequently controversial— issue in the national media during the period under study.

Expectations about future house prices have traditionally been considered a central determinant for the optimality of purchasing versus renting. By increasing the expected profitability of investing in housing, higher future house prices increase the desirability for owning.[2] The role of expectations on housing tenure choice is a well studied relationship in housing literature. Both theoretical papers (e.g Ortalo-Magné and Rady, 2002; García-Montalvo, 2006)[3] and survey studies (e.g. Case and Shiller, 1988, 2003; García-Montalvo, 2006) agree that expectations about future house prices have an important weight on households' decisions.[4] However, to the best of my knowledge there is an important lack of studies on the distributional implications of biased expectations being heterogeneously distributed across the population.

One would expect the distributional effects of heterogeneous expectations to be stronger in periods of high price volatility such as housing bubbles, when arguably subjective beliefs about future prices might tend to diverge most across the population. The main question that motivates this paper is to identify the main winners and losers in the housing market when significantly biased expectations about future house prices spread across the population affect equilibrium prices.

To answer this question, I first build a theoretical two-period model extending Ortalo-Magné and Rady 2002 by including a continuum of agents, with biased information affecting beliefs about the future evolution of house prices and income with a different intensity for every agent, which produces the desired heterogeneity of expectations across the population. After the benchmark model with correct expectations, the second scenario shows the implications of biased expectations af-

[1] For example, The Economist's global house-price indicators estimated the overvaluation of Spanish house prices in 2003 to be slightly over 60%, versus 53% in Britain and the Netherlands, 48% in Ireland, 28% in Australia and 14% in the US (The Economist, 2003).

[2] The traditional approach to model the desirability of buying vs. renting is based on the *user cost* of housing, which estimates the annual cost of owning a house taking into account the opportunity cost of alternative investment possibilities (e.g Hendershott and Slemrod, 1982; Poterba, 1984; Himmelberg et al., 2005). Several empirical studies show that differences in user costs between these two tenure options are significant factors in the household's decision, see Rosen and Rosen 1980; Hendershott and Shilling 1980; Goodman 1988 or Green 1996.

[3] In different publications, García-Montalvo puts forward the expectational hypothesis for the Spanish case, further developed in this paper.

[4] Subjective beliefs about house prices have recently become also important in the macroeconomic literature, particularly following Adam et al. 2012. By considering subjective beliefs, their model can account for important facts which have been traditionally difficult to explain, such as the heterogeneous response of house prices across the G7 following the reduction in interest rates at the beginning of the millennium.

fecting only households, the demand side of the economy. In the third scenario, heterogeneously distributed over-optimism affects both landlords and households. This extension of the model gives predictions about how heterogeneous expectations might increase equilibrium prices given an inelastic supply of houses, and identifies the winners and losers in this market as compared to their expected outcome under perfect information.

The main predictions from the model regarding household behavior are tested in the framework of the last Spanish housing bubble, exploiting the relevance of publicly available information for the formation of expectations across the population. The main objective of this empirical exercise is to explore whether heterogeneous expectations about future house prices spread across Spanish households during the last years of the housing bubble, and if so, whether these diverse expectations were distinct enough as to affect the market behavior of different households in the different directions predicted by the model. Concretely, unless extremely high expectations about future house prices implied that buying completely dominated renting during this period, highly overvalued housing prices should make those relatively better-informed households, *ceteris paribus*, less likely to purchase a house in the years before the burst of the bubble than those households which were arguably worse informed. A brief description of the main facts observed during the years of the Spanish housing bubble might lend context to better explain why this might have been the case.

With the entrance of Spain into the European Monetary Union in 1994, the country began a period of sustained economic growth. Between 1997 and 2008, the 'bubble years', real GDP growth averaged an annual 3.5% (significantly higher than the EU average for the same period). The population increased from 39.5 to 46 million (4.6 million of which were immigrants), unemployment halved from 16% to 8%, and historically high real interest rates converged to European levels, even going negative in the period 2002-2005.[5] Pushed in part by this expansive economic environment, 6.5 million new houses were built during these years and, as we can see in Figure 1.3 in appendix 1.6.1, house prices increased 180% in nominal terms.

Together with most financial institutions and real estate builders, the Spanish government systematically neglected the possibility of a real estate bubble.[6] As late as October 2007, just a few months before the bubble crashed, the Housing Minister infamously declared that 'Spain has the best real estate sector in the world'.

While fundamentals were known to be responsible for a large part of the rise in house prices, as early as 2003 there was a broad agreement among academic economists and economic institutions about the existence of a real estate bubble in the country. Montalvo 2002 and the Servicio de Estudios del BBVA 2002 study 'Situación inmobiliaria' estimated around 28% of the price of houses in Spain to correspond to a bubble component, while The Economist reported this to be over 60% according to the 'price to earnings ratio' (The Economist, 2003). The Spanish housing bubble

[5] See Corsetti et al. 2011 for a description of the evolution of the Spanish economy between 1990 and 2011.

[6] In words of Arellano and Bentolila 2009 the government did not do anything to inform the population about the possibility of a bubble and its potential risks for families and for the economy as a whole.

became a common topic in the specialized and non-specialized press.[7] By the end of the year, the European Commission officially warned the Spanish government about the high risk posed by the national real estate sector.

We do not know to which extent these warnings were effective in transmitting moderate expectations about future house prices to the population, but we do know these were definitely not moderate among house buyers. García-Montalvo 2006, in a survey among households that bought their dwelling between 2000 and 2005, found the expected average annual house prices growth for the next 10 years to be 23.4%.[8] With studies and news repeatedly warning about the existence and risks of the bubble since 2003, one would not expect everybody to have these extreme beliefs. Assuming that the intensity with which warnings about these dangers reached different families diverged in the short run,[9] we should expect expectations about the future evolution of house prices to diverge significantly across the Spanish society in the years following 2003. That is, a proportion of the population should have had at least more realistic expectations about the future of the Spanish real estate market. Controlling for income, we should expect lower average expectations among those who did not choose to buy a house. Unfortunately, surveys were carried only among house buyers.

In the empirical part of the paper I test the main predictions from the theoretical model regarding household behavior. I do so by studying which variables are significant to explain households' decision to purchase their main dwelling between 1999 and 2002, and compare the coefficients in this regression with those for the periods 2003-2005 and 2006-2008. The lack of explicit information on expectations in the data for this period[10] implies that the empirical part of the paper must rely on a central assumption: that the level of education of the head of household is a good indicator of economic knowledge, as will be later argued. Following this assumption, this variable is used as an indirect proxy for capacity to have subjective expectations about future prices closer to the objective distribution.[11]

The main empirical result is that while education was not significant to explain a household's decision to purchase its main dwelling before 2002, it was highly significant and negative between 2003 and 2005. While this result should be taken with caution as it is based on proxy variables, it serves as suggestive evidence supporting

[7] According to García-Montalvo, the number of times that 'housing bubble' and 'Spain' appeared together in the same article in the main Spanish newspapers went from 141 in 2002 to 640 in 2003.

[8] While this question might have not been the most appropriate, as arguably not everyone has a perfect understanding of compounding percentages, it does make the point of the prevalence of extremely optimistic expectations among house-buyers. Also relevant for this paper, in this same survey those house-buyers with lower socioeconomic status were found to be significantly more over-optimistic in their expectations than those with a higher one. A similar survey found this same average expectation to be 13.8% for the US in 2003 (Case and Shiller, 2003).

[9] Divergence of beliefs in the short run when there exist biased sources of information is a standard result in the literature on social learning and information transmission, see for example Golub and Jackson 2010.

[10] Acknowledging their potential relevance for households' economic behavior, subjective expectations have been included in the questionnaire for the 2011 wave. Using these data, subjective expectations about future house prices have been found to be important for predicting spending behavior, both for housing investment and car purchases (Bover, 2015).

[11] Notice this means just better, or equivalently less-biased expectations, and not necessarily accurate ones.

the main hypotheses of the paper. Namely, that there was an important degree of heterogeneity in expectations about future house prices across the Spanish society before the burst of the bubble; that their distribution was related to education and access to information; and that this had an important effect on the market behavior of Spanish households during this period. Controlling for the main variables considered important for household tenure choice, between 2003 and 2005 in Spain households with more years of education, arguably better informed on average, were less likely to purchase their main dwelling than those with less years of education.

The remainder of the paper is organized as follows. Section 2 presents the different scenarios of the theoretical model, which are compared in section 3. The empirical analysis is developed in Section 4. Section 5 concludes.

1.2 The model

The theoretical model is an extension of Ortalo-Magné and Rady 2002. I drop the assumption of having low and high quality houses available and assume that all houses are of the same kind.[12] As they do for low quality houses, the utility derived from housing consumption is independent of the tenure regime,[13] and normalized to zero. This implies that in this model households derive all their utility from non-housing consumption. After the first scenario I introduce subjective and potentially biased probabilities for each state of the world across the population. These will be heterogeneously distributed, with some agents being relatively better informed and others relatively worse.

1.2.1 Correct expectations, the benchmark model

A two-period economy is populated by a continuum of risk-averse households and risk-neutral landlords. Let N denote the set of households, and M denote the set of landlords, both with (Lebesge) measure normalized to 1. In this economy there are two commodities, houses and a consumption good that serves as numeraire. This good can be saved or borrowed across periods at the exogenous interest rate r.

Landlords initially own their main dwelling, which they do not trade, and an extra house which they can either rent or sell. They represent the supply side of the housing market. Their only role in this model is to trade their extra house, maximizing their expected profit under the assumption of risk neutrality.

It is assumed that every household must live in a house at every period. The utility derived from housing consumption is independent of the tenure choice and normalized to zero. Hence, households derive utility only from the consumption of the numeraire good, maximizing their expected lifetime utility. Since all houses give the same utility to their occupiers, they are assumed to have the same market value.

[12] As shown in appendix 1.6.2, considering houses of different types does not have any important implication for the effects of introducing biased information into the model.

[13] This is a standard assumption in the literature, since those advantages from either owning or renting which are not purely economical are arguably highly subjective.

For each household $i \in [0,1]$ the utility function $U(c_i)$ is strictly increasing $U'(c_i) > 0$, strictly concave $U''(c_i) < 0$, and agents maximize lifetime consumption, $U(c_i) = U(c_{i1} + c_{i2})$,[14] where the sub-indexes 1 and 2 indicate non-housing consumption in the corresponding period.

Each household faces uncertainty regarding both its income and the cost of housing in period 2. With probability π the economy will be in state H in this period, while with probability $1-\pi$ it will be in state L. Each state is characterized by the rental price of housing in period 2, with $R_H > R_L$.

Endowments W_{iH} and W_{iL} are expressed in second-period units of the numeraire good. Each household receives its corresponding endowment once the state of the world is realized in period 2. Households are uncertain about the state of the world that will be realized, but they know their own endowment in each case. As in the model by Ortalo-Magné and Rady, given the rate for borrowing across periods r, households enjoy the numeraire good only in period 2, when they receive their endowment.[15]

W_{iH} and W_{iL} will generally be different for different households. In principle it is not imposed $W_{iH} > W_{iL}$, or any restriction on the sign of the endowment difference $\Delta_i = W_{iH} - W_{iL}$.

This last point implies that the covariance between a household's endowment and second period rental price

$$Cov[W_i, R_2] = \pi(1-\pi)(R_H - R_L)(W_{iH} - W_{iL}), \tag{1.1}$$

can potentially take any real value.

Arbitrage from the part of landlords implies that the price of a house in period 1 is equal to first-period rent plus the discounted expected value of second-period rent:

$$p_1 = R_1 + \frac{\bar{R}_2}{1+r}, \tag{1.2}$$

with $\bar{R}_2 = \pi R_H + (1-\pi)R_L$. Hence, buying a house in period 1 amounts to lock-in the second-period rent at its expected level, providing insurance against rent fluctuations. For each household, the optimality of buying or renting in period 1 will depend on the covariance between second period income and house rents.[16] The reason is that they care about the riskiness of their consumption, not about the riskiness of the stream of housing expenditures. Notice that the structure of this problem implies that market clearing conditions are already built into the model: the distribution of income across households will totally determine the proportion of them that will choose to purchase their house in period 1, or renting it in both

[14] The utility function being strictly increasing implies non-satiation of preferences. Strictly concavity implies risk aversion.

[15] Agents receiving their endowment of the numeraire good only in the second period and caring only about life-time consumption are two simplifying assumptions, which facilitate focusing on the implications of consumption-smoothing across different states of the world.

[16] Since the economy finishes in period 2, buying a house in the last period is equivalent to renting it, and so the price of a house in period 2 is the same as its rental cost.

periods, without any impact on equilibrium first-period prices —which will always be established at the fair price p_1.

According to the different possible tenure choices and states of the world, lifetime consumption for any household i, expressed in period-2 units of the numeraire good will be given by:

1. $c_{iH}^B = W_{iH} - (1+r)R_1 - \bar{R}_2$, when buying and the realized state is H.
2. $c_{iL}^B = W_{iL} - (1+r)R_1 - \bar{R}_2$, when buying and the realized state is L.
3. $c_{iH}^R = W_{iH} - (1+r)R_1 - R_H$, when renting and the realized state is H.
4. $c_{iL}^R = W_{iL} - (1+r)R_1 - R_L$, when renting and the realized state is L.

Since $R_H > \bar{R}_2 > R_L$, 1 is always preferred to 3, and 2 is always less preferred than 4 i.e. when second period prices are high households will be ex-post better-off if they have chosen to buy in period 1, while if state L is realized they will be better-off if they have chosen to rent their dwelling in both periods. Importantly, the expected level of non-housing consumption is independent of the tenure choice, $E(c^B) = E(c^R)$. Tenure choice determines how stochastic shocks translate into non-housing consumption fluctuations.

The problem faced by a household is that of choosing the tenure mode that maximizes his expected utility. The expected utility when buying is given by

$$\pi U(c_{iH}^B) + (1-\pi)U(c_{iL}^B), \tag{1.3}$$

and the expected utility when renting by

$$\pi U(c_{iH}^R) + (1-\pi)U(c_{iL}^R). \tag{1.4}$$

A household will choose to buy a house in period 1 if and only if

$$\pi[U(c_{iH}^B) - U(c_{iH}^R)] > (1-\pi)[U(c_{iL}^R) - U(c_{iL}^B)], \tag{1.5}$$

i.e. if expected gains from buying are larger than the expected gains from renting.

It is assumed that, given the fair price p_1, all households have enough income to choose whether to rent or to buy their dwelling, being able to pay the due amount to the corresponding landlord,[17] independently of the realized state of the world.[18]

Decreasing marginal utility of consumption implies that the tenure decision depends on the covariance between housing expenditure and households' endowment. To show it clearly, equation 1.5 above is rewritten as

[17] This is guaranteed simply by establishing $W_{iL}^{min} > p_1(1+r)$.

[18] Under this scenario, introducing constrained agents is straightforward and would not be interesting for the analysis of the model. Basically, credit constrained agents would only be allowed to rent their dwelling in both periods, without any general equilibrium effects, as house prices are fixed by now. This will change in section 3, when price is established in equilibrium.

$$\pi[U(W_{iH} - (1+r)R_1 - \bar{R}_2) - U(W_{iH} - (1+r)R_1 - R_H)]$$
$$> (1-\pi)[U(W_{iL} - (1+r)R_1 - R_L) - U(W_{iL} - (1+r)R_1 - \bar{R}_2)]. \quad (1.6)$$

Let's first focus on the left hand side. As $c_{iH}^B > c_{iH}^R$ (because $\bar{R}_2 < R_H$), given decreasing marginal utility, if W_{iH} increases by δ, $U(c_{iH}^B)$ will increase by less than $U(c_{iH}^R)$. Hence, this part of the equation is decreasing on W_{iH}. Similarly, since $c_{iL}^R > c_{iL}^B$, the RHS is decreasing on W_{iL}. Putting these two effects together we get the following result:

Lemma 1: Preference for purchasing a house in period 1 is inversely related to $\Delta_i = W_{iH} - W_{iL}$.

As Δ_i decreases, the covariance between endowments and rental prices decreases, so households' consumption fluctuates less when purchasing their dwelling in period 1. Similarly, as Δ_i increases, the covariance between endowments and rental prices increases, and renting becomes more preferable. Everything else equal, households prefer to rent their house in both periods when the covariance between their income and house prices is higher, and prefer to buy it in period 1 when this is smaller. This is a direct implication of risk averse preferences. Given this result, for a given expected endowment[19] $\overline{W} = \pi W_{iH} + (1-\pi)W_{iL}$, the optimal tenure choice can equivalently be defined as a function of either the endowment difference Δ_i or as a function of the covariance between second period income and renting costs $Cov[W_i, R_2]$. From now on it is assumed that every household i has the same expected endowment $\overline{W}$.

The following analysis characterizes the critical value $\bar{\Delta}$, below which it is preferable for a household to buy in period than to rent in both periods:

1. For $\Delta_i = 0$, $W_{iH} = W_{iL} = \overline{W} = W$, equation (6) is re-written as $U(W - (1+r)R_1 - \bar{R}_2) > (1-\pi)U(W-(1+r)R_1 - R_L) + \pi U(W-(1+r)R_1 - R_H)$. Jensen's inequality tells us that for $E(c_i^B) = E(c_i^R)$, (since in this case $c_i^B = E(c_i^B)$,[20] and $c_{iL}^R \neq c_{iH}^R$), and a strictly concave function $U(.)$, $E[U(c_i^B)] > E[U(c_i^R)]$. The LHS is always larger than the RHS. It will always be preferable for the household to buy. Since the optimality of buying is decreasing on Δ_i, this implies $\bar{\Delta} > 0$.

2. Similarly, for $\Delta_i = W_{iH} - W_{iL} = R_H - R_L$ buying exposes the agent to consumption variations, while by renting its dwelling, household's income fluctuations exactly offset rent fluctuations. In this case it is always preferable to rent.

Without any assumption on the distributions of W_{iH}, W_{iL} or Δ_i, we can conclude that $0 < \bar{\Delta} < (R_H - R_L)$.

Lemma 2: The threshold $\bar{\Delta}$ that determines whether it is optimal for a household to rent its dwelling in both periods or to buy it in period 1 exists, belongs to the

[19] For the special case of CARA utility functions, tenure choice is independent of the level of expected income.

[20] Since when buying an agent knows his consumption level ex ante, as this is independent from second period realizations.

interval $[0, R_H - R_L]$ and it is unique.

To show existence and uniqueness of the critical $\bar{\Delta}$ is straightforward. We have just seen that for $\Delta_i = 0$, $E[U(c_i^B)] > E[U(c_i^R)]$ and for $\Delta_i = R_H - R_L$, $E[U(c_i^R)] > E[U(c_i^B)]$. This, together with the monotonicity in $\partial E[U(c_i^B)] \ /\partial \Delta_i < 0$ and $\partial E[U(c_i^R)]/\partial \Delta_i > 0$, for every Δ_i, implies that the critical value $\bar{\Delta}$ exists and it is unique. The expected utility from buying is a monotonically decreasing function of Δ_i, that always takes a higher value than the expected utility of renting for $\Delta_i = 0$. The expected utility from renting is a monotonically increasing function of Δ_i, that takes a higher value than the expected utility from buying for $\Delta_i = R_H - R_L$, so they must cross at a single point in the interval $[0, R_H - R_L]$.

Proposition 1: Having the correct expectations, every household with $\Delta_i < \bar{\Delta}$ will find it optimal to buy its dwelling in the first period, while every household with $\Delta_i > \bar{\Delta}$ will find it optimal to rent its dwelling in both periods. Households' with $\Delta_i = \bar{\Delta}$ are ex-ante indifferent between buying or renting. *Direct from lemmas 1 and 2.*

The previous analysis implies that any household with $\Delta_i > (R_H - R_L)$ would find it optimal to rent its dwelling in both periods, while any household with $\Delta_i < 0$ would find it optimal to purchase its dwelling in period 1. Hence, only endowment values in the range $\Delta_i \in [0, R_H - R_L]$ are interesting for the analysis of households' optimal tenure choice decision. For simplicity, from now on the analysis will be restricted to values of Δ_i that belong to this interval.[21] In order to facilitate the analysis, the distribution of Δ_i is normalized, dividing it by $\Delta_{max} = R_H - R_L$, and so transforming its original support into $[0, 1]$. This results in the new threshold $\hat{\Delta}$, and individual endowment differences $\tilde{\Delta}_i$, for which all the previous results apply. The details of this normalization are given in appendix 1.6.3.

With the new notation, when agents have the correct expectations, for a given level of expected income $\overline{W}$ it is optimal to rent for every household with $\tilde{\Delta}_i > \hat{\Delta}$, and it is optimal to buy for every household with $\tilde{\Delta}_i < \hat{\Delta}$. Agents with $\tilde{\Delta}_i = \hat{\Delta}$ are ex-ante indifferent between buying or renting.

The next section studies the effects of introducing misspecified beliefs into the model.

1.2.2 Households with biased expectations

It is now assumed that households receive information about the probability of each of the two possible states of the world from two different sources. One source gives them the correct information, that state H will happen with probability π. The other source communicates biased information, telling households that the probability of state H happening in period 2 is $\pi + \epsilon$. ϵ is the information bias parameter, as it indicates the direction and magnitude of the error contained in the wrong information. ϵ is the same for every household, and it is bounded to belong to $-\pi \leq \epsilon \leq 1 - \pi$, such that the wrong message does not attach negative probability to any of the events.

[21] Notice the objective here is to simplify the exposition of the theoretical analysis, and this is not meant as an empirical assumption. A negative correlation between individual income and house prices is clearly something feasible, which one would expect to find in the data.

Heterogeneity in beliefs comes from agents' different exposition, trust or understanding of each information source. Those relatively better-informed households are more exposed to the correct information, or equivalently trust it more. Those relatively worse-informed agents are more exposed to the wrong information, or place a higher trust on it. To account for this heterogeneity I introduce a new parameter α_i, which determines the weight the wrong information has in household i's beliefs, and for simplicity assume $\alpha_i \sim U[0,1]$ over the measure-1 set N of households.

For a given ϵ, a household with a certain α_i attaches probability

$$q_i = \pi + \alpha_i \epsilon \tag{1.7}$$

to state H and

$$(1 - q_i) = 1 - (\pi + \alpha_i \epsilon) \tag{1.8}$$

to state L.

The positive trust on the biased information means beliefs are now misspecified, in that they do not necessarily forecast the probability of each second-period state accurately. In the case $\epsilon > 0$, households will tend to believe that state H is more likely to happen than it really is. I will call this misbelief optimism. In the case of $\epsilon < 0$ they will attach a larger probability than a perfectly informed agent to state L. I will refer to this as pessimism. The paper focuses on the first case. It is generally trivial to extend results to the case $\epsilon < 0$.

Given ϵ, α_i determines the distance between agent i's belief and the truth. A household with $\alpha_i = 0$ places all its trust on correct information, and so knows exactly the right probability attached to each state of the world. The larger is α_i, the further away that an agent's expectations are from the right ones.[22]

The subjective expected life-time utility for a household with $\alpha_i \in [0,1]$, when buying his dwelling in period 1 is

$$q_i[U(c_{iH}^B)] + (1 - q_i)[U(c_{iL}^B)], \tag{1.9}$$

In the case with $\epsilon > 0$, this is now larger than the expected utility when choosing to buy in the correct expectations case, $\pi[U(c_{iH}^B)] + (1 - \pi)[U(c_{iL}^B)]$, since for $\epsilon > 0$ and $\alpha_i \neq 0$, $\pi < q_i$. Household are optimistic, they over-estimate the probability of house prices being high in the second period. Buying is now optimal for household i if and only if

$$q_i[U(c_{iH}^B) - U(c_{iH}^R)] - (1 - q_i)[U(c_{iL}^R) - U(c_{iL}^B)] > 0. \tag{1.10}$$

Some of the households which would optimally rent having the correct expectations, will now choose to buy. The higher probability they attach to H will compensate for a larger correlation between income and house prices.

[22] The correct expectations model can be seen as a special case of this one. If either ϵ is equal to 0 or α_i is equal to 0 for all agents, the value of the other parameter does not have any effect. In both cases the economy would be the one described in the previous section.

When biased expectations affect only households, the critical $\hat{\Delta}$, below which it is optimal to buy, becomes $\hat{\Delta}_i(\alpha_i, \epsilon)$, a function of the weight an agent places on wrong information α_i, and the information bias parameter ϵ. For any given distribution of endowments $\{W_{iH}, W_{iL}\}_{i\in[0,1]}$ that produces a continuous distribution of $\tilde{\Delta}_i$ in the interval $[0, 1]$, the following two results apply:

Lemma 3: For each value of ϵ there exists a unique function $\hat{\Delta}(\alpha_i, \epsilon)$, such that all the agents with a combination of $\tilde{\Delta}_i$ and α_i that places them below this function choose to buy their house in the first period, with implied aggregate demand $D(\epsilon)$. All the agents above $\hat{\Delta}(\alpha_i, \epsilon)$ choose to rent their dwelling in both periods. *This result follows the same reasoning as the analysis of $\bar{\Delta}$ in the previous section.*

Proposition 2: The amount of houses demanded is monotonically increasing on ϵ, $dD(\epsilon)/d\epsilon > 0$.

As ϵ decreases, expectations about future prices being high decrease across the population, what will result in $D(\epsilon_2) < D(\epsilon_1)$ for $\epsilon_2 < \epsilon_1$. To see this assume that there was an initial ϵ_1 before the market opened, and that this decreased to ϵ_2 before trade begun. Some agents that were very close to the function $\hat{\Delta}(\alpha_i, \epsilon_1)$ by below will change their choice after knowing the new ϵ_2. These agents must have switched from buying to renting, pushed by lower expected renting costs at $t = 2$. Given p_1 is fixed,[23] no agent will choose to buy its dwelling in period 1 given ϵ_2 if under ϵ_1, expecting higher renting costs, he was choosing to rent in both periods. The opposite reasoning explains why increasing ϵ increases the demand for houses. This is illustrated by the implications that each of the different values ϵ can take[24] will have for the housing market:

1. For $\epsilon = 1 - \pi$ the biased information communicates that state H will happen with probability 1, what an agent with $\alpha_i = 1$ will believe. This corresponds to the case with the largest possible level of optimism, and so with the largest number of households choosing to buy in period 1.

2. For any value $1 - \pi < \epsilon < 0$, the biased information communicates that the probability of state H is higher than it really is. The function that gives the critical value for each individual, $\hat{\Delta}(\alpha_i, \epsilon)$, will be below $\hat{\Delta}(\alpha_i, 1 - \pi)$ and above $\hat{\Delta}(\alpha_i, 0)$ and so, more individuals will choose to buy than in the case with correct expectations, but less than in the case with $\epsilon = 1 - \pi$.

3. For $\epsilon = 0$, $\hat{\Delta}(\alpha_i, 0) = \hat{\Delta}$, the scenario in which the whole population has correct expectations. All agents take the ex-ante -objectively- optimal decision given their particular α_i: to buy if $\tilde{\Delta}_i < \hat{\Delta}$ and to rent if $\tilde{\Delta}_i > \hat{\Delta}$.

4. For $0 > \epsilon > -\pi$, the biased information communicates that state H is less likely to happen than it really is. Less individuals will choose to buy than having the right expectations.

5. For $\epsilon = -\pi$ the biased information communicates that the state H will happen

[23] Landlords continue to have correct beliefs about the probability attached to each of the possible states of the world. This will imply that previous assumptions on house price determination still hold and this remains the same, $p_1 = R_1 + \frac{\bar{R}_2}{1+r}$.

[24] Remember that for the biased information to not attach negative probability to any of the states of the world it must be that $\epsilon \in [-\pi, 1 - \pi]$

with probability 0, what an agent with $\alpha_i = 1$ will believe. This corresponds to the maximum possible level of pessimism, and so with the lowest number of households choosing to buy.

The two following results hold:

Proposition 3: The proportion of the population taking a sub-optimal decision is monotonically increasing on the absolute value of ϵ.

As $|\epsilon|$ increases and ϵ gets further away from 0, the wrong information is more biased. Since α_i is fixed, more people having more biased beliefs will imply that the proportion of the population taking sub-optimal decisions will increase.

Lemma 4: The sub-optimality of the decision made by an agent with a combination of $\tilde{\Delta}_i$ and α_i that places him in the area between $\hat{\Delta}(\alpha_i, 0)$ and $\hat{\Delta}(\alpha_i, \epsilon)$, as measured by the loss in -objective- expected utility, is monotonically increasing on $|\tilde{\Delta}_i - \hat{\Delta}|$.

While the relative accuracy of beliefs influences each household's i decision, the level to which this decision diverges from the ex-ante objective optimal choice is only determined by the shortest distance between its position $(\alpha_i, \tilde{\Delta}_i)$, and the function $\hat{\Delta}(\alpha_i, 0) = \hat{\Delta}$.

To illustrate these results I assume $\tilde{\Delta}_i \sim U[0,1]$. This is obtained with the endowments for each $i \in [0,1]$ given by $W_{iH} = \overline{W} + (1-\pi)i(R_H - R_L)$ and $W_{iL} = \overline{W} - \pi i(R_H - R_L)$. It is easy to check that for $i = 0$, $W_{iH} = W_{iL} = \overline{W}$ and $\Delta_i = 0$. For $i = 1$, $W_{iH} - W_{iL} = (R_H - R_L) = \Delta_{Max}$ and in general, for any value of i, $\Delta_i = W_{iH} - W_{iL} = i(R_H - R_L) \Rightarrow \Delta_i/(R_H - R_L) = \tilde{\Delta}_i = i$, at the same time that $\pi W_{iH} + (1-\pi)W_{iL} = \overline{W}$ for the whole population. This implies that $F(\tilde{\Delta}_i) = i$ and so[25] $\tilde{\Delta}_i \sim U[0,1]$ is satisfied for the measure of households on [0,1].

For $\alpha_i \sim U[0,1]$, $\tilde{\Delta}_i \sim U[0,1]$, and a given ϵ, the measure of those choosing to buy their dwelling is given by the area under $\hat{\Delta}(\alpha_i, \epsilon)$, such that:

$$D(\epsilon) = \int_0^1 \hat{\Delta}(\alpha_i, \epsilon)\, \mathrm{d}\alpha_i. \tag{1.11}$$

Figure 1.1 illustrates which households choose to buy and which choose to rent for a value of ϵ in each of the different intervals that this parameter might belong to.[26]

[25] $F(.)$ refers to the cumulative density function.

[26] The lines for each $\hat{\Delta}(\alpha_i, \epsilon)$ are drawn straight for simplicity. Their curvature will depend on the shape of the utility function, being more convex for larger degrees of risk aversion.

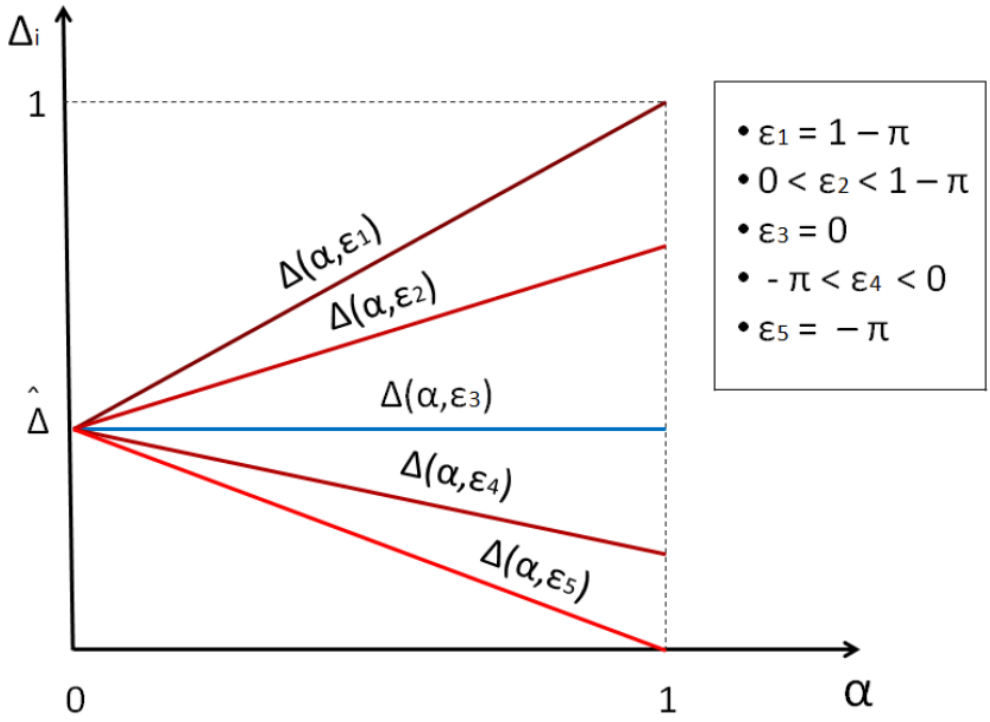

Figure 1.1 – The area under each line corresponds to the proportion of the population purchasing their main dwelling in period 1 given the corresponding biased information parameter, when this affects only households.

Any house purchased by households with a combination of α_i and $\tilde{\Delta}_i$ over the perfect information line $\hat{\Delta} = \hat{\Delta}(\alpha_i, 0)$ gets them a lower —objective—expected utility than what they would get by renting. Any house rented by households with a combination of α_i and $\tilde{\Delta}_i$ under this same line will imply an expected utility lower than what they would get by buying. The proportion of the population that will take a suboptimal decision for each given value of ϵ is simply computed as the absolute value of the difference between the proportion of the population which buys under biased expectations and the proportion of the population which would buy under the correct expectations, formally:

$$\int_0^1 \hat{\Delta}(\alpha_i, \epsilon)\, \mathrm{d}\alpha_i - \int_0^1 \hat{\Delta}(\alpha_i, 0)\, \mathrm{d}\alpha_i. \tag{1.12}$$

In the next section misspecified beliefs are also introduced in the supply side of the housing market.

1.2.3 Biased expectations affecting both households and landlords

In this section the previous model is modified by assuming that the biased information affects also landlords, in the same way that it affects households. Hence, under this scenario, landlords also place a weight $\alpha_j \sim U[0, 1]$ on a source communicating

biased information, which tells them that the probability of state H happening is $\pi + \epsilon$.

Since landlords do not consume, this change only affects the supply side of the economy, which is not perfectly competitive anymore. Heterogeneous expected probabilities for each state imply that different landlords consider different prices to be fair. Hence, the market price will be determined in equilibrium and for any $\epsilon \neq 0$ it will be different from the objective fair price, $p_1 = R_1 + \bar{R}_2/(1+r)$.

For any $\epsilon \neq 0$, each landlord $j \in [0,1]$ that places a weight $\alpha_j > 0$ on the wrong information believes the expected renting price in the second period to be $\tilde{R}_{j2} = q_j R_H + (1-q_j)R_L \neq \bar{R}_2$, where the subjective probability attached to state H, $q_j = \pi + \alpha_j \epsilon$ is defined in the same way as for households. The minimum price he will accept, is given by the subjective income he now expects to receive from renting his extra house in both periods:

$$\hat{p}_j(\alpha_j, \epsilon) = R_1 + \frac{\tilde{R}_{j2}}{1+r}. \tag{1.13}$$

For the case $\epsilon > 0$, any landlord with $\alpha_j > 0$ believes this expected income from renting, $\hat{p}_j(\alpha_j, \epsilon)$, to be larger than p_1. The larger α_j, the more optimistic the landlord, and so the larger price that he will require in order to choose to sell his extra house in period 1.

Lemma 5: For fixed R_H and R_L, $\alpha_j \sim U[0,1]$ and a given ϵ, there exists a linear function $\hat{p}(\alpha_j, \epsilon)$ that gives the perceived fair price for each landlord $j \in [0,1]$, and it is unique.

This result comes directly from the distribution of $\alpha_j \sim U[0,1]$, and the definitions of q_j and $\tilde{R}_{j2}$ given above, which imply that for a given ϵ the unique subjective fair price for every landlord is aggregated across the whole population, in the function $\hat{p}(\alpha_j, \epsilon)$. The left chart in Figure 1.2 shows this function for different values of ϵ. It is straightforward to observe that the subjective fair price for landlord j increases with ϵ, formally $d\hat{p}_j(\alpha_j, \epsilon)/d\epsilon > 0$ for every landlord j. Notice that by construction, the subjective fair price is bounded to belong to the closed interval defined by the minimum and the maximum possible prices, $\hat{p}_j(\alpha_j, \epsilon) \in [p_{Min}, p_{Max}]$.[27]

The closed-form solution for the supply function is directly derived[28] from the perceived fair price line $\hat{p}(\alpha_j, \epsilon)$ as:

$$\alpha^*(p, \epsilon) = S(p, \epsilon) = \frac{(1+r)(p - p_1)}{\epsilon(R_H - R_L)}. \tag{1.14}$$

This expression for $\alpha^*(p, \epsilon)$ corresponds to those landlords who have a —subjectively—perceived fair price $\hat{p}_j(\epsilon)$ lower than the price p. For a given price p supply

[27] The maximum possible price $p_{Max} = R_1 + R_H/(1+r)$ is the minimum price that will be accepted by an optimistic landlord who beliefs that state H will happen with probability 1. Similarly, the minimum possible price $p_{Min} = R_1 + R_L/(1+r)$ is the subjective fair price for a pessimistic landlord who beliefs that state L will happen for sure.

[28] See appendix 1.6.4 for the derivation.

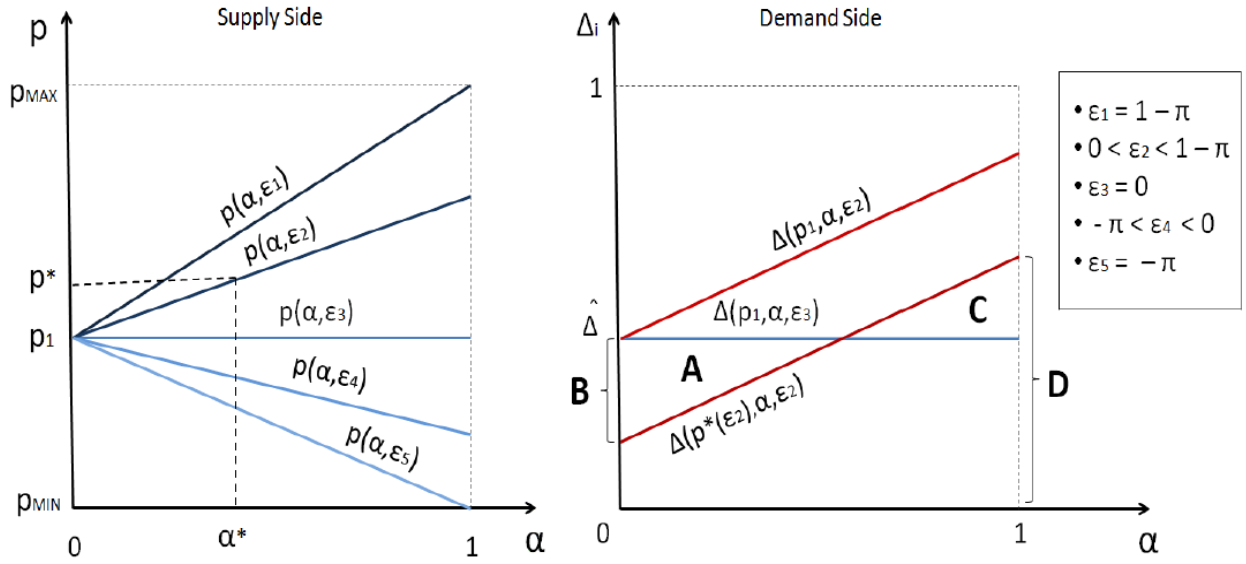

Figure 1.2 – Supply side (LHS) and demand side (RHS) of the housing market with both landlords and households having biased expectations

decreases with ϵ, $\partial\alpha^*(p,\epsilon)/\partial\epsilon < 0$. Notice that for $\epsilon > 0$ and $p = p_1$, supply is equal to 0. With $D(p_1) > 0$, an equilibrium in the housing market requires the price to be established at a value $p^*(\epsilon)$ higher than p_1. For a given ϵ, $\alpha^*(p^*(\epsilon),\epsilon)$ gives the total supply of houses being sold in equilibrium.

Recovering the assumption $\tilde{\Delta}_i \sim U[0,1]$ and $\epsilon > 0$, a price higher than p_1 implies that the curve $\hat{\Delta}(p_1,\alpha_i,\epsilon)$ shifts down to $\hat{\Delta}(p^*(\epsilon),\alpha_i,\epsilon)$, where p^* is the equilibrium price. This will be established at the value $p^*(\epsilon)$ that makes the proportion of landlords willing to sell their extra house equal to the proportion of households willing to buy their house in the first period, $S(p^*(\epsilon),\epsilon) = D(p^*(\epsilon),\epsilon)$. See the RHS of Figure 1.2, which shows the case $\epsilon = \epsilon_2$.

Formally the demand for houses in period 1 for a given p and ϵ is given by[29]

$$D(p,\epsilon) = \int_0^1 \hat{\Delta}(p,\alpha_i,\epsilon)\,\mathrm{d}\alpha_i, \tag{1.15}$$

or equivalently

$$D(p,\epsilon) = 1 - \int_0^1 \alpha_i^*(p,\epsilon)\,\mathrm{d}\tilde{\Delta}_i. \tag{1.16}$$

The last expression allows us to write the demand function in analytical form, since the critical α_i^* which makes a household i with a given endowment distribution $\{W_{iH}, W_{iL}\}$, indifferent between renting and buying, can be expressed as a function of $\tilde{\Delta}_i$ as:[30]

[29] Assuming no households are constrained. The equilibrium effects of introducing constrained agents do not modify the analysis significantly, see appendix 1.6.6.

[30] See appendix 1.6.5 for the derivation.

$$\alpha_i^*(p,\epsilon) = \frac{-\pi\left(U(c_{iH}^B) - U(c_{iH}^R)\right) + (1-\pi)\left(U(c_{iL}^R) - U(c_{iL}^B)\right)}{\epsilon\left(U(c_{iH}^B) - U(c_{iH}^R) + U(c_{iL}^R) - U(c_{iL}^B)\right)}, \tag{1.17}$$

when this expression lies within the interval $[0,1]$. $\alpha_i^*(p,\epsilon)$ takes value 0 when the RHS in this last expression becomes negative, and 1 when it becomes larger than this same value. Consumption in each state is now given by:

$$c_{iH}^B = \overline{W} + (1-\pi)\tilde{\Delta}_i(R_H - R_L) - (1+r)p,$$
$$c_{iL}^B = \overline{W} - \pi\tilde{\Delta}_i(R_H - R_L) - (1+r)p,$$
$$c_{iH}^R = \overline{W} + (1-\pi)\tilde{\Delta}_i(R_H - R_L) - (1+r)R_1 - R_H,$$
$$c_{iL}^R = \overline{W} - \pi\tilde{\Delta}_i(R_H - R_L) - (1+r)R_1 - R_L.$$

The price $p^*(\epsilon)$ will be determined in equilibrium as the price that clears the market for houses sold in period 1,[31] i.e. $S(p^*(\epsilon),\epsilon) = D(p^*(\epsilon),\epsilon)$.

Definition 1: An equilibrium of the housing market with biased expectations affecting both landlords and households, is given by an equilibrium price, amount of houses supplied and amount of houses demanded $\{p^*(\epsilon), S(p^*(\epsilon),\epsilon), D(p^*(\epsilon),\epsilon))\}$, such that the market clears, $S(p^*(\epsilon),\epsilon) = D(p^*(\epsilon),\epsilon)$.

For a given distribution of rental prices in each state of the world R_H, R_L, a given continuous distribution of endowments $\{W_{iH}, W_{iL}\}_{i\in[0,1]}$,[32] and a given ϵ, the following result applies:

Proposition 4: The equilibrium price $p^*(\epsilon)$ that clears the housing market at $t=1$ exists, it is unique and strictly increasing on ϵ.

This is proven for the case $\epsilon > 0$, without loss of generality. Now, with optimistic landlords, there are not houses being supplied at p_1. The market begins with $D(p_1,\epsilon) > S(p_1,\epsilon)$ and so, p increases until the point in which $D(p^*(\epsilon),\epsilon) = S(p^*(\epsilon),\epsilon)$. Since the demand for houses is monotonically decreasing on the price p and the supply for houses is monotonically increasing on p,[33] $p^*(\epsilon)$ must be unique. Given the equilibrium exists, monotonicity of supply and demand with respect to ϵ,[34] also imply that $p^*(\epsilon)$ is increasing on ϵ.[35] For any $\epsilon_1 > \epsilon_2$, $\hat{p}(\alpha_j,\epsilon_1)$ is strictly above $\hat{p}(\alpha_j,\epsilon_2)$, see the left chart of Figure 1.2 (vertical axis).[36]

Figure 1.2 shows the equilibrium price for ϵ_2, $p^*(\epsilon_2) = p^*$ such that $\alpha^*(\epsilon_2) = \alpha^*$ on the LHS of the figure is equal to the area below $\hat{\Delta}(p^*(\epsilon_2),\alpha_i,\epsilon)$ on the RHS. α^* gives

[31] Remember that in the previous two scenarios in which landlords have perfect information, the market price p is set by arbitrage to be equal to the "fair price" p_1, independently of period-1 demand.

[32] For a given p_1, the only restriction on the distribution of endowments is that at $t=1$ there must be some households interested in buying and some households interested in renting, and that this is also the case for $p_1 + \lambda$, for $\lambda > 0$ arbitrarily small. The main condition on endowments is that these must be large enough, see appendix 1.6.6.

[33] Proof in appendix 1.6.8.

[34] See appendix 1.6.8.

[35] Proof in appendix 1.6.9.

[36] The same reasoning gives uniqueness for any $\epsilon \in [-\pi, 0)$, with $S(p_1,\epsilon) > D(p_1,\epsilon)$ in this case. The equilibrium price will be lower than the fair one. The equilibrium for $\epsilon = 0$ is trivially equivalent to the benchmark case.

us the proportion of landlords who find it optimal to sell their extra house, while the area under $\hat{\Delta}(p^*(\epsilon_2), \alpha_i, \epsilon)$ gives the proportion of households choosing to buy in period 1.

It has been shown that the equilibrium price $p^*(\epsilon)$ is increasing on ϵ under general conditions. The effect of increasing this parameter on the quantity of houses traded in period 1, as compared to the scenario with correct expectations, is ambiguous. There are two opposed effects, higher ϵ makes choosing to buy more desirable for households, but at the same time it decreases landlords' willingness to sell. Which effect dominates will depend on the concrete parameters of the model, and on the utility function chosen, $U(.)$.[37]

The main results derived from the introduction of heterogeneity in expectations are robust to the endogenization of second-period renting prices R_H and R_L, as a function of p. For an analysis of the main results when second period prices are endogenous see appendix 1.6.10.

1.3 Comparing the three scenarios: social welfare

The welfare criterion chosen is based on the principle of utilitarian efficiency, particularly appropriate to compare outcomes from an ex-ante point of view when choices involve risk.[38] Given that the final outcome depends on the concrete realization of uncertainty in period 2, the main interest here is to compare agents' expected utilities in the different scenarios considered. Inefficiency is caused by misspecified beliefs, which imply that subjectively perceived expected utility will be in general different from objective expected utility.

The equilibrium with all agents having correct expectations is ex-ante efficient, since subjective and objective expected utility coincide for every household i. This is the fully optimal scenario that will be used as benchmark for comparison.

In the second scenario, with households having biased expectations while landlords have the correct ones, efficiency is lost as a direct consequence of biased information affecting the demand side of the economy. For a given $\epsilon \neq 0$, all those agents with a combination of $\tilde{\Delta}_i$ and α_i that places them between the functions $\hat{\Delta}(\alpha_i, \epsilon)$ and $\hat{\Delta}(\alpha_i, 0)$, are taking an ex-ante sub-optimal decision. Among the agents placed in this area, those with a higher α_i, relatively worse informed, will tend to have a higher loss of expected utility. On the supply side, since the price of houses in period 1 does not change, landlords have the same ex-ante expected income independently of selling or renting their extra house, and hence the same expected utility as in the first scenario.

Assuming that biased expectations affect all the agents in the economy has interesting implications, which are particularly appropriate to relate this model to the

[37] Notice that this is the case because the number of houses is fixed in this model. If over-optimistic landlords were given the possibility of building new houses and assuming the cost is less than their expected price, we would see a larger supply of houses than in the benchmark scenario. By May 2013 there were 3.4 million of empty houses in Spain.

[38] See for example Harsanyi 1953, 1955 or Vickrey 1960.

housing tenure choice of Spanish families in the immediate period after 2003. This case is compared with the two previous scenarios.[39]

First of all, we see that introducing biased expectations on the supply side of the economy pushes house-prices up. This has important re-distributive implications. All landlords with $\alpha_j < \alpha^*(\epsilon)$ are selling their extra house at $p^*(\epsilon)$, over the fair price p_1, and so they are ex-ante better off than in the two previous scenarios. The remaining $1 - \alpha^*(\epsilon)$ landlords, who are relatively worse informed and will choose to rent their extra house in both periods, have an objective expected income equal to p_1 and so they are ex-ante as well as before. On the demand side, all those households choosing to buy, below the function $\hat{\Delta}(p^*(\epsilon), \alpha_i, \epsilon)$ are paying $p^*(\epsilon)$, higher than the fair price. Households that choose to buy in period 1 are paying for an overpriced house, with the money going to those relatively better-informed landlords. Hence, over-optimistic expectations affecting both sides of the market imply a transfer of wealth from the demand to the supply side of the economy, making the set of landlords better off, while those households that choose to buy are ex-ante worse off than in the two previous scenarios.

Because of the increase in price from p_1 to $p^*(\epsilon)$, the proportion of households choosing to buy their house in period 1, D in the RHS of Figure 1.2, is smaller than in the second scenario, when landlords have the correct expectations. The difference in demand between these two situations is given by the amount of agents with a combination of $\tilde{\Delta}_i$ and α_i that places them between the functions $\hat{\Delta}_i(p^*(\epsilon), \alpha_i, \epsilon)$ and $\hat{\Delta}_i(p_1, \alpha_i, \epsilon)$. There are two different groups of agents who choose not to buy as a consequence of higher equilibrium prices. The relatively better-informed agents who have a lower covariance between their income and period-2 house prices (A on the RHS of figure 1.2) will rent their main dwelling in both periods. They do not make their optimal choice because of the higher price, and as a consequence are ex-ante worse-off than in the two previous scenarios. For the second group, (corresponding to the area B-A on the RHS of figure 1.2), the increase in equilibrium prices pushes them to their objectively optimal choice, renting in both periods. They are ex-ante as well-off in this scenario as in the benchmark case with correct expectations, and better-off than in the scenario in which biased expectations affect only households and the equilibrium price remains lower. These households are saved from a bad decision by higher prices.

Among the agents that still find it optimal to buy under $p^*(\epsilon)$ (D on the RHS of figure 1.2), there are also two well-differentiated groups. In this case though, higher prices will make both of them worse-off than in the previous scenarios. Those agents placed in the area D-C, with a relatively low covariance between house prices and income, will buy their main dwelling in the three scenarios. They are worse-off in the third one just because they are getting their house at a higher price. Those relatively worse-informed households above $\hat{\Delta}(p_1, \alpha_i, 0)$ (C on the RHS of Figure 1.2) choose to buy in the third scenario, given a higher price, even when with the correct expectations they would not optimally do so under the lower p_1. These agents will be the big losers if state L is realized in the second period, as in this state of the world they will have a relatively low income while facing the high price contracted at $t = 1$.

[39] Again, the extension of the analysis for the case $\epsilon < 0$ is trivial.

With respect to quantities, for the case $\epsilon > 0$, the amount of houses traded in period 1 is highest in the second scenario. How this quantity compares between scenarios 1 and 3 depends on the concrete parameters chosen.

1.4 Empirics

1.4.1 The data and the empirical model

The data used in this study are the *Banco de España*'s 'The Spanish Survey of Household Finances (EFF)'. This data set consists of three waves of cross-sectional data coming from surveys corresponding to the years 2002, 2005 and 2008, with information about the income, assets, debts, consumption and demographic characteristics of Spanish households. An important element of the EFF is that the second and third waves contain a panel component. A refreshment sample by wealth has also been incorporated in those waves, to preserve their cross-sectional representativity. There are observations for 5143 families in 2002, 5962 in 2005 and 6195 in 2008. Of those, 1925 households participate in the three waves, 2580 participate both in 2002 and 2005, and 3967 participate both in 2005 and 2008.

In this section, I study the determinants of housing tenure choice for Spanish families in three different periods: 1999-2002, 2003-2005 and 2006-2008. All those households which already own their main dwelling by the initial year considered are dropped from the sample, together with those who have acquired their house during this period but not purchasing it under market prices (for example inheriting it or receiving it as a donation). In the final sample, those who own their dwelling by the last year of the corresponding time interval have purchased it in that period.

The wrong or biased information (corresponding to ϵ in the theoretical model) is associated with those news and opinions which were pushing individuals to think that prices would continue to rise at a high rate for many years, during the last years of the bubble.[40] The correct information is associated with studies and news which since the last months of 2002 were predicting either a soft landing or a sharp decrease in house prices, and to any news or conversations communicating this message. For those years, the theoretical model predicts those households whose beliefs were more influenced by the correct information to have, *ceteris paribus*, a lower tendency to buy their dwelling than those with beliefs more influenced by the wrong information.

Unfortunately, the data does not contain any measure of economic information or knowledge across the households in the sample. Questions about expectations on future house prices were not included in any of these three survey waves either.[41] The crucial assumption for this empirical study is that more educated individuals tend to have a better knowledge of the economy. This is supported by empirical papers such as Walstad 1997, who studies the determinants of public understanding of important economic issues, using a survey on American economic literacy from

[40] The source of this information can be for example a conversation with an over-optimistic friend, or any declaration in the media which neglects the possibility of house prices growth to slow down in the near future.

[41] As noted in the introduction, these have been included later, for the 2011 wave.

1992. One of his main findings is that, *ceteris paribus*, people with more years of education are more likely to understand conditions in the national economy better. In the context of the Spanish housing bubble, it is assumed that those agents with more education were more likely to get in contact with studies and news[42] warning about the expected contractionary evolution of the Spanish real estate sector in the near future, and were also more likely to better understand the implied risks. Hence, I identify the education level of the head of household as a proxy for a higher economic understanding, which in this set-up translates in more accurate, less over-optimistic expectations about the future evolution of house prices.

A similar reasoning follows for the inclusion of the variables *finance* and *riskaverse*, where the first is a dummy which takes value 1 if the households has any kind of investment in financial markets. The second variable, *riskaverse* takes value 1 if the household invests in mutual funds but not in the stock market, following an arguably less risky investment strategy. A household with financial investments is more likely to follow the evolution of different markets and prices closer than the average citizen, and arguably to have better access to information or economic advise from relatively well informed agents. Hence, I take *riskaverse* as a proxy for an agent having a better than average access to the right information about the expected evolution of house prices, and being at the same time more risk averse that the average investor.[43] The theoretical model, in which risk aversion plays a central role, suggests that these agents should be less likely to purchase their main dwelling between 2003 and 2005. The complete list of variables used in the study is given by:[44]

- *purchase*, a dummy variable which takes value 1 when the household owns its main residence by the end of the corresponding period and 0 when it does not. In order for this variable to reflect the decision of purchasing the dwelling, we exclude from the regression those households who get their dwelling in this same time interval but not at market prices, either through inheritance, purchasing social housing, or as a donation.
- *more_educ*, a dummy value indicating the education level of the head of household. It takes value 1 when this has attained secondary education or higher,[45] and 0 for primary education or lower.
- $finance$, is a dummy variable which takes value 1 if the household has any investments in financial markets, 0 otherwise.
- $riskaverse$, a dummy variable taking value 1 if the household invests in financial markets, but only in mutual funds, and not directly in the stock market.

[42] Either directly or indirectly, for example with conversations with relatively well informed friends.

[43] It might be argued that banks should inform all of their customers adequately if they were to have privileged information, since they do not want to lose money with defaulting loans. The dominant regime for mortgages in Spain, the 'dación en pago' or 'deed in lieu of foreclosure', which dictates that the customer is liable for the amount of money received, and giving back the property does not cancel the full debt, arguably decreased banks' incentives to monitor loans and advise customers on their best interest.

[44] See table 1.1 for descriptive statistics.

[45] The dummy variables *highschool* for secondary education and *university* are included in a robustness check.

It takes 0 otherwise.

- *income*, household's income, in 10,000 euros. This is given by the income in 2002 for the regression for the period 1999-2002, and by the average between the income in the starting year and the income in the final year for those regressions for the intervals 2003-2005 and 2006-2008.

- *stddev_income*, the standard deviation of income divided by the mean of household's income, for the starting and the end year in the corresponding time interval.[46]

- *cov_inc_price*, the covariance between the household's income and the index for house prices,[47] for the starting and the end year in the corresponding time interval.[48]

- *otherprop*, the value of other real estate properties owned by the households, in 10,000 euros. Arguably, other properties could be used as collateral, facilitating access to credit.

- *employee*, $self-employed$ and *retired*, dummy variables which take value 1 if the professional situation of the head of household by the start of the period corresponds to that category, and 0 otherwise. The reference category is *unemployed*.

- *age dummies*, the age of the head of the family, comprising 6 different age intervals.

- *number_members*, the number of household members.

[46] Robst et al. 1999 find that individuals with a larger income uncertainty are less likely to own their dwelling.

[47] The chosen price index for houses takes a value of 1.667 for 2002, 2.286 for 2005 and 2.905 for 2008. Given frequent experts' criticisms of the official statistics about the house prizes reported by the Spanish Government, see for example Arellano and Bentolila 2009, or Vergés 2008, for the period in the sample, I choose to use the price index reported by *Sociedad de Tasación*, a private institution regulated by the *Bank of Spain*. These are substantially higher than the prices reported by the Housing Ministry.

[48] In a study closely related to the predictions of the basic Ortalo-Magné and Rady 2002 model, Davidoff 2006 finds that households whose incomes covary relatively strongly with housing prices tend to own relatively little housing.

	1999-2002	2003-2005	2006-2008
Purchase	0.31	0.31	0.37
Income (10,000 €)	3.45	3.00	3.50
More_educ	0.54	0.45	0.48
Highschool	0.25	0.19	0.21
University	0.28	0.26	0.27
Finance	0.26	0.20	0.21
Riskaverse	0.05	0.06	0.07

Table 1.1 – Descriptive statistics for those households which do not own their main dwelling by the start of the corresponding period, excluding those which have negative wealth, and those which get their dwelling in the corresponding period but not purchasing it at market prices (inheritage, public housing or donation). The table gives the proportion for each dummy variable, and the mean for *income*. Sample size is 193 for the period 1999-2002, 169 for the period 2003-2005 and 263 for the period 2006-2008.There are two main reasons for the small sample size. First, the Spanish house-ownership ratio has been historically very high, estimated 78,8% by Eurostat for 2015. Second, the EFF has an oversampling of wealthy families, most of which already own their main dwelling by the start of the corresponding period.

Using a probit model, purchasing or not a house in the corresponding period is regressed on a dummy variable reflecting the lower or higher education level of the head of the family, *finance*, *riskaverse*, a measure of household's income and the set of controls, found to be important in most empirical studies:

$$purchase_i = \alpha_0 + \alpha_1 more\_educ_i + \alpha_2 finance_i + \alpha_3 riskaverse_i + \\ \delta_1 income_i + \delta_2 stddev\_income_i + \delta_3 cov\_inc\_price + X_i\beta + \epsilon_i, \quad (1.18)$$

where X_i is a vector of control variables, ϵ_i is an iid robust standard error.

The same model is run for the three different periods, 1999-2002, 2003-2005 and 2006-2008. The theoretical mechanism suggested in the paper, together with the information circulating across the Spanish society at the time, imply that we would expect the effect of economic information to take different signs across these different time intervals.[49]

I assume that the relation between education or information, income and the housing tenure decision of a family are constant across regions.[50] The survey has an

[49]Including credit constrained households could bias the coefficients in these regressions, since they should not be able to buy a home even if they wanted to. These are filtered by dropping those households which declare to have a negative net wealth by the initial year of the corresponding time interval.

[50]The survey takes care of the geographical representativity of the sample at the regional level. In our study, sample size when considering only those families which did not own a house at the start of the corresponding period is too small for any analysis at a lower-than-national level. It must be said that in the Spanish case, overvalued house prices were a geographically widespread phenomenon during the bubble years.

oversampling of wealthy families. To ensure that the results of this study are representative of the Spanish population, probability weights for each observation are included in the regressions.[51]

For 1999-2002 the possibility of a bubble in the Spanish housing sector had not been a salient issue either in economic studies or the media, and so the mechanism suggested by the theoretical model might not be at play. One would expect either a zero or a positive coefficient associated to the variables *more_educ* and *riskaverse*. The heterogeneity of expectations about future prices is expected to matter the most for the second period considered, implying that the coefficients associated with these two variables should take a negative value for the interval 2003-2005. The situation for the period 2006-2008 is uncertain.

Naturally, for this empirical exercise to be valid, the level of education of the head of household and *riskaverse* must not be factors affecting the purchasing decision negatively by themselves. While the impact of alternative time-varying effects cannot be ruled out, comparing the results for the period 2003-2005 and 2006-2008 with the results for the period 1999-2002 should show, at least, that there is not a stable negative relation between education or investing in mutual funds and the probability of choosing to purchasing the household's main dwelling in any period. Also, empirical studies tend to find a positive relation between education, participation in financial markets, and house ownership, see for example Painter et al. 2001.

The following section describes the empirical results corresponding to each of these periods.

1.4.2 Results

Table 1.2 shows one regression for each of the time periods under study. Column (1) corresponds to the determinants of purchasing the main dwelling between 1999 and 2002. Column (2) gives the results for the period 2003 to 2005, and similarly column (3) shows the results for the years between 2006 and 2008. Each of the regressions includes all the controls described in the previous section, robust standard errors, and probability weights.

As prescribed by the theoretical model, and against the traditionally expected sign for these coefficients, for the period 2003 to 2005, column (2) shows negative and highly significant coefficients for both *education* and *riskaverse*. The interpretation of this result is straightforward. Those households with higher levels of education have in average a 31.9% lower probability of purchasing their main dwelling in this period. Investing in financial markets through participating in mutual funds but not in stocks, arguably reflecting being highly risk averse and relatively well informed, is associated with a 20.8% lower probability of purchasing the main dwelling between 2003 and 2005. Notice that as expected, none of these variables is associated with a lower probability of purchasing the main dwelling between 1999 and 2002, see column (1). For the period 2006-2008 none of these variables is statistically significant.

[51] The main results hold also without including probability weights, see table 1.4 in appendix 1.6.11.

	(1) purchase	(2) purchase	(3) purchase
more_educ (d)	0.0604	-0.319***	-0.0573
	(0.54)	(-3.27)	(-0.49)
finance (d)	-0.0795	0.0976	0.0554
	(-0.61)	(0.37)	(0.31)
riskaverse (d)	0.637***	-0.208***	0.277
	(5.99)	(-4.15)	(0.93)
income	0.0752***	0.0240	-0.0299
	(3.41)	(0.75)	(-1.00)
stddev_income	-0.610***	-0.301	0.0717
	(-2.86)	(-1.55)	(0.32)
cov_inc_price	1.56e-08*	1.40e-08	3.07e-08*
	(1.70)	(1.19)	(1.80)
controls	YES	YES	YES
Observations	193	169	263

Marginal effects; t statistics in parentheses

(d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.2 – Marginal effects, probit: explaining the decision to purchase the main dwelling for those households which do not own it by the start of the period. 1999-2002 (column 1), 2003-2005 (column 2), 2006-2008 (column 3).

This result, associating more years of education and investing in mutual funds to a lower probability of purchasing the main dwelling between 2003 and 2005, but not before this period, is robust to different specifications.[52] The results in the regression which includes *highschool* and *university* instead of *more_educ* show the expected monotonic relationship existing between a higher education level and a lower probability of purchasing the main dwelling between 2003 and 2005, see table 1.3 in appendix 1.6.11. Equivalent results hold if the same model is run without probability weights (table 1.4, appendix 1.6.11), including also households with a negative wealth at the start of the period (table 1.5, appendix 1.6.11), or keeping households which got their house through inheritance, social housing or a donation in the regression (1.6, appendix 1.6.11). Taking all those households which appear both in 2002 and 2005 and using the same model to study the determinants of owning their main dwelling by 2002 —independently of when they purchased their property —shows that the results with this larger sample are also consistent with the current hypothesis, as neither *more_educ* nor *riskaverse* have a negative coefficient, see table 1.7 in appendix 1.6.11.

As for the other variables of interest, *finance* does not have a significant coefficient, which might be explained by the expected relatively lower risk aversion of these

[52]The possibility of multicollinearity between the main independent variables in the model, namely *more_educ*, *riskaverse* and *income* might seem a natural concern given their nature. However, an econometric test using variance inflation factors (VIF) applied to the equivalent OLS regressions does not find any signal of multicollinearity between these variables.

households as compared to those agents which have both *finance* and *riskaverse* equal to 1, given the relevance of risk aversion for the suggested mechanism. As expected, *income* has always a positive coefficient when this variable is statistically significant, and *stddev_income* a negative one, indicating that households with a higher income variability are less likely to purchase their main dwelling.[53]

Hence, the main results are consistent with the predictions of the theoretical model. The crucial result is that the level of educational attainment of the head of household is not significantly related to having purchasing the main dwelling between 1999 and the year 2002, but as predicted it has a negative and highly significant coefficient for the period 2003-2005. Similarly, having investments in a mutual fund (*riskavarse*) is positively associated to the probability of a household purchasing its main dwelling between 1999 and 2002 and as predicted by the theory, the coefficient associated to this variable becomes much larger and negative between 2003 and 2005.

While this is only descriptive evidence, the theoretical mechanism put forward in this paper points towards the relation between *education* and *riskaverse* and the associated access to accurate information and a better economic understanding, as the cause of the negative sign of these variables in the regression explaining the decision to purchase a house between 2003 and 2005. If this is truly the case, these results indicate that heterogeneous expectations about house prices inflation did exist and had a significant influence on the market behavior of Spanish households during the last years of the housing bubble. *Ceteris paribus*, those relatively better-informed households would have been less likely to buy a house, while those relatively worse-informed ones would have been more likely to choose buying over renting during this period. This relationship was strong between 2003 and 2005 and disappeared after 2006.

1.5 Conclusion

The main objective of this paper is to study both theoretically and empirically the distributional effects of biased expectations about house prices, when these are heterogeneously distributed across the population. The suggested mechanism might be particularly relevant during housing bubbles, specifically in those periods before the burst which are characterized by generalized over-optimism.

To explore this problem, I first extended a simple two-period model introducing biased expectations, producing qualitative predictions which are very similar to what we observe in periods of housing bubbles. Houses are overpriced, those landlords who choose to sell get an extra income as compared to the perfect information scenario, and households which choose to buy are ex-ante worst off than in the scenario with correct expectations, as they pay a higher price. By showing the existence of a wealth transfer from the demand to the supply side of the economy, the model points towards biased information having similar effects as decreased market competition,

[53]The positive coefficient associated to *cov_inc_price* in the regressions in which this variable is significant might be explained by the fact that, in a period of growing house prices, this variable takes higher values for households with a currently increasing income. These should be more likely to purchase a house.

possibly creating incentives for one part of the agents in the economy to try to keep biased, over-optimistic beliefs across the population.

Applying the model to the case of the Spanish housing bubble, high price levels might have kept some relatively better-informed households away from buying when they would probably like to do it under lower prices. Other households, relatively worse informed and with relatively pro-cyclical incomes, bought a house pushed by extremely over-optimistic beliefs. Many of these households fell into a particularly weak economic position. Many of those families suffering an eviction during the years after the burst of the bubble[54] are likely to belong to this group.

The empirical study uses the education attainment of the head of household as a proxy for its economic knowledge, and participation in a mutual fund as a proxy for having better access to economic information, while being more risk averse than the average investor. In this context, after 2003 these variables should translate into having more moderate expectations on house price inflation and a lower preference for risky investments. Assuming this identification method is valid, I find significant evidence of those households relatively better informed being less likely to buy a house during the period 2003-05, when the bubble and its potential risks should be known and understood by part of the population but not necessarily by everybody.

The results in this paper complement the previous literature in several directions. First of all, by showing that heterogeneity of beliefs matters, it gives evidence from market behavior on the traditionally assumed important role of expectations about future prices on the housing tenure choice of households. Secondly, related to the literature on learning and non-fully-rational expectations, it indicates that the level of economic knowledge, directly related to education and access to important information, might be an important element at the origin of the distribution of heterogeneous beliefs across the population, and that these might have important implications for the economic behavior of households, in decisions as important as purchasing or renting their main dwelling.

These findings have important policy implications, as they clearly emphasize the high relevance of warning the population of the possibility of a drop in house prices and its risks in times of a bubble, in order to reduce as much as possible the negative effects of its burst.

[54]The number of foreclosures of real estate properties in Spain (not all of them for a household's main dwelling) has shown a sharp increase in the years after 2008, with 16,097 in 2006, 17,412 in 2007, 20,549 in 2008, 37,677 in 2009, 54,250 in 2010, 64,770 in 2011, and 75,375 in 2012, according to the official data published by the Spanish Government (Respuesta del Gobierno, (186) Solicitud de informe a la administración pública del Estado Congreso 186/696, 04/04/2013, Lara Moya, Cayo).

1.6 Appendix

1.6.1 The Spanish housing bubble, 1997-2008

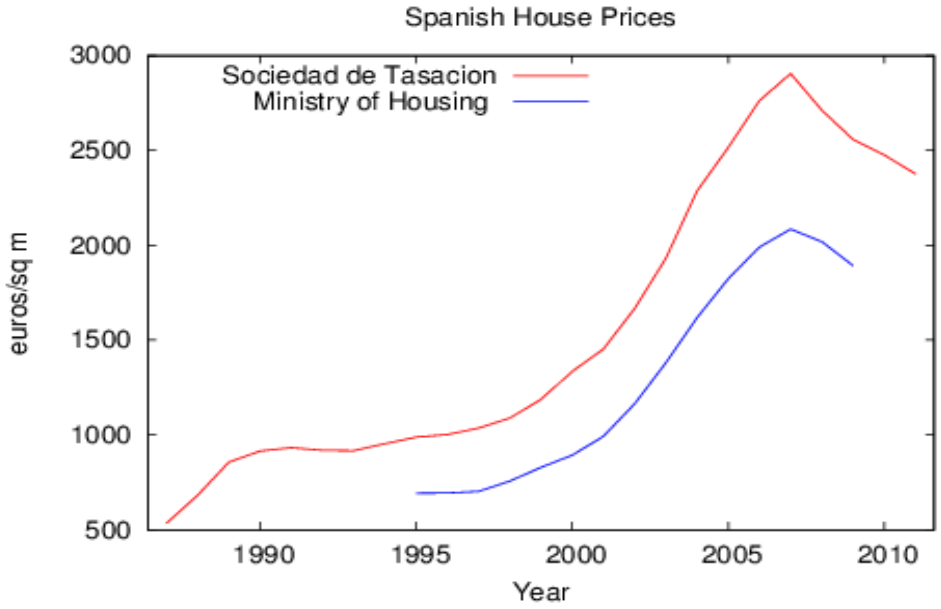

Figure 1.3 – Evolution of Spanish house prices. Data taken respectively from 'Sociedad de Tasación' and 'Ministerio de Vivienda'.

1.6.2 A note on different housing consumption plans

In this model I have abstracted from Ortalo-Magné and Rady 2002 assumption on the existence of two different types of houses, a high-quality or type 1 house, which gives the agents a fixed extra utility, and a low-quality or type 0 house, which utility is normalized to zero. Each household has an exogenous housing consumption plan, which determines in which type of house it plans to live in period 1, and then on period 2, conditionally on which state of the world is realized. Given that including houses of different qualities allows for agents to use house purchases as an investment, it is an useful exercise to analyze how this change would affect the results of this model. This will allow us to answer interesting questions such as, which would be the effect of introducing over-optimistic beliefs for households that plan to sell their house moving to a cheaper one, if state H is realized? As we will see, over-optimistic beliefs will make it more preferable to buy in period one than under the correct expectations, independently of the housing consumption plan.

Basically, in their model it is first assumed that the rent of low-quality houses does not fluctuate in the second period, such that $R^0 = R^0_H = R^0_L < R_L$, where R_L refers to high quality houses rental price in state H. This implies that the tenure choice of households choosing to live in a type 0 home in period 1 does not matter[55] and the analysis is restricted to the case in which agents choose to live in a high quality

[55]Under this assumption, both renting the low quality house in both periods or buying it at $t = 1$ has the same cost.

house in period one. I follow their approach and assume that all the households in this model live in a high quality house in period 1. As they affirm in their paper, it is straightforward to abstract from the previous assumption about low quality houses with equal price across periods and derive analogous results for households starting in a type 0 home. The distribution of consumption plans across the continuum of households would affect the equilibrium in Scenario 3, making the analysis highly complicated and not very interesting. Hence, the analysis of the effect of introducing different consumption plans in the model is restricted to scenario 2, when biased expectations affect only households, but not the supply side of the economy [56]. Ortalo-Magné and Rady define a housing consumption and tenure choice plan as $(1_x, h_H, h_L)$, where $x = B$ if the household buys a type 1 house and $x = R$ if the household rents a type 1 house in period one. h_H and h_L denote, respectively, in which type of house the household will live in period 2, depending on which state of the world is realized.

Their optimality condition, corresponding to (6) in the benchmark model is:

$$\begin{aligned}\pi[&U(W_H - (1+r)R_1 - h_H R_H - (1-h_H)R^0 + R_H - \bar{R}_2) \\ &- U(W_H - (1+r)R_1 - h_H R_H - (1-h_H)R^0)] \\ &> (1-\pi)[U(W_L - (1+r)R_1 - h_L R_L - (1-h_L)R^0) \\ &- U(W_L - (1+r)R_1 - h_L R_L - (1-h_L)R^0 - [\bar{R}_2 - R_L])] \quad (1.19)\end{aligned}$$

From this expression, which holds for every consumption plan, it is clear that a positive ϵ, by increasing the perceived probability of state H happening, will make buying (LHS) more preferable than it is when having the correct expectations. Substituting h_H and h_L by 1 we see that the analysis in this model corresponds to the case $(1_x, 1, 1)$, in which a family chooses whether to buy or to rent planning to remain in the same -high quality- house also in period 2. The intuition for why $\epsilon > 0$ increases the desirability of buying for each of the other possible consumption plans is given by:

1. $(1_x, 1, 0)$: The household plans to live in a high quality house if H is realized and to rent a cheaper one in period 2, if state L is realized, increasing its consumption by $R_L - R^0$. A higher ϵ makes it more desirable to buy in period one, since otherwise when H is realized the household would have to pay more to rent a high-quality house in both periods, and this is perceived as more likely to happen.

2. $(1_x, 0, 1)$: The household plans to sell its high-quality house if state H happens, in order to increase its consumption with the difference $R_H - R_0$ and plans to remain in the house if prices at $t = 2$ happen to be low, R_L. Higher $prob(H)$ implies that the household believes it is more likely that he will make a profit from selling the high quality house that it can choose to purchase in period 1, and so buying is more preferable than when having correct expectations.

[56] Since the main focus here is on the effects of introducing different consumption plans on households' choices, I abstract from modeling the supply side of the economy. The assumption taken is that the structure of the supply side is such that the prices of low quality houses are fixed at R^0 in both periods, and the price of high quality houses at p_1

3. $(1_x, 0, 0)$: The household plans to move to a low quality house in the second period, independently of the state of the world realized. Again $\epsilon > 0$ increases the profitability of buying, this time because $R_L - \bar{R}_2 < 0 < R_H - \bar{R}_2$ implies that buying is a good investment when prices at $t = 2$ are high, while it is a bad investment when prices are low. Hence, the highest it is $\pi + \epsilon$ the most desirable it is buying for the household.

Hence, the main message from this analysis is that the results derived from introducing over-optimistic, heterogeneous expectations, hold for any potential consumption plan. By introducing $\epsilon > 0$ buying becomes more preferable for any household than it would be knowing the correct probability π. Those relatively worse-informed, more over-optimistic, would tend to buy more. Naturally, the opposite happens for $\epsilon < 0$. Since this is the main mechanism behind the dynamics of the model, we would expect the results of introducing biased expectations also among landlords, when considering the possibility of different consumption plans, to be qualitatively equivalent to those described in section 3.3.

1.6.3 A normalization

In order to facilitate the analysis the distribution of Δ_i is normalized, transforming its original support $[0, R_H - R_L]$ into $[0, 1]$.

Notice that $Cov(W_i, R_2)$ is directly proportional to Δ_i. The individual with the largest possible covariance between income and house prices in period 2 will have $\Delta_{Max} = W_{iH} - W_{iL} = R_H - R_L$. Each household's Δ_i is normalized dividing it by $\Delta_{Max} = R_H - R_L$.

Hence, from now on I will use $\tilde{\Delta}_i = \Delta_i / \Delta_{Max}$ as the parameter indicative of each household's covariance between W_i and R_2.

We see that for the extreme cases 1 and 2 in the characterization of $\bar{\Delta}$, $\Delta_i = 0 \Rightarrow \tilde{\Delta}_i = 0$ and $\Delta_i = W_{iH} - W_{iL} = R_H - R_L \Rightarrow \tilde{\Delta}_i = 1$, respectively, so $\tilde{\Delta}_i \in [0, 1]$. From now on I will use $\hat{\Delta}$, the normalization of $\bar{\Delta}$ as the critical value, where $\hat{\Delta} = \bar{\Delta} / \Delta_{Max}$.

Notice that propositions 1, 2 and 3 still hold, with $\tilde{\Delta}_i$ being equivalent to Δ_i and $\hat{\Delta}$ being equivalent to $\bar{\Delta}$.

1.6.4 Analytical form for the supply function

Using the perceived fair prices for the worst and the best informed landlords, respectively:

$$(\hat{p}_j | \alpha_j = 0) = R_1 + \frac{\pi R_H + (1 - \pi) R_L}{1 + r},$$

and

$$(\hat{p}_j | \alpha_j = 1) = R_1 + \frac{(\pi + \epsilon) R_H + (1 - \pi - \epsilon) R_L}{1 + r},$$

and the fact that α_j goes from 0 to 1, we can get the slope of the line $\hat{p}(\alpha_j, \epsilon)$ as the difference $(\hat{p}_j|\alpha_j = 1) - (\hat{p}_j|\alpha_j = 0)$, giving

$$\frac{d\hat{p}(\alpha_j, \epsilon)}{d\alpha_j} = \frac{\epsilon[R_H - R_L]}{1 + r}.$$

Then, for a given ϵ it is straightforward —see the left chart in Figure 1.2—to obtain the supply $\alpha^*(p, \epsilon)$ as

$$S(p, \epsilon) = \frac{(1 + r)(p - p_1)}{\epsilon(R_H - R_L)}$$

1.6.5 Analytical form for the demand function

Let us define, for a given ϵ and price p, the gain in expected utility from buying over renting for agent i to be $\tilde{U}_i(p, \epsilon)$, given by

$$\tilde{U}_i(p, \epsilon) = E[U(Buy|\alpha_i, p, \epsilon)] - E[U(Rent|\alpha_i, p, \epsilon)].$$

Agent i will choose to purchase her dwelling in period 1 if and only if $\tilde{U}_i(p, \epsilon) > 0$. From this expression -assuming log utility-[57] a critical value α_i^* is derived as:

$$\tilde{U}_i(p, \epsilon) = 0 \iff (\pi + \alpha_i^*\epsilon)[ln(c_{iH}^B) - ln(c_{iH}^R)] - (1 - \pi - \alpha_i^*\epsilon)[ln(c_{iL}^R) - ln(c_{iL}^B)] = 0$$

giving[58]

$$\alpha_i^*(p, \epsilon) = \frac{-\pi ln(a_i)}{\epsilon ln(a_i b_i)} + \frac{(1 - \pi) ln(b_i)}{\epsilon ln(a_i b_i)},$$

with a_i and b_i given by

$$a_i(p) = \frac{c_{iH}^B}{c_{iH}^R} = \frac{\overline{W} + (1 - \pi)\tilde{\Delta}_i(R_H - R_L) - (1 + r)p}{\overline{W} + (1 - \pi)\tilde{\Delta}_i(R_H - R_L) - (1 + r)R_1 - R_H},$$

and

$$b_i(p) = \frac{c_{iL}^R}{c_{iL}^B} = \frac{\overline{W} - \pi\tilde{\Delta}_i(R_H - R_L) - (1 + r)R_1 - R_L}{\overline{W} - \pi\tilde{\Delta}_i(R_H - R_L) - (1 + r)p}.$$

The expression of the different consumption levels as a function of $\tilde{\Delta}_i$ is obtained from the definition of this variable

$$\tilde{\Delta}_i = \frac{W_{iH} - W_{iL}}{R_H - R_L},$$

[57] Log utility is chosen here to show a more compact analytical form. The derivation of the general case displayed in equation (1.16) follows the same steps.

[58] The shape of this function imply that the integral in the expression for $D(p, \epsilon)$ can only be solved using numerical methods.

together with the definition of the expected income for each household, $\pi W_{iH} + (1 - \pi)W_{iL} = \overline{W}$. Using these two expressions it directly derives:

$W_{iH} = \overline{W} + (1 - \pi)\tilde{\Delta}_i(R_H - R_L)$,

$W_{iL} = \overline{W} - \pi\tilde{\Delta}_i(R_H - R_L)$.

Then, $a_i(p)$ and $b_i(p)$ above are obtained, fully characterizing the analytical expression for the critical α_i^* for each household i -together with $\alpha_i^* = 0$ if $\alpha_i^*(p, \epsilon) < 0$ and $\alpha_i^* = 1$ if $\alpha_i^*(p, \epsilon) > 1$-. Integrating this function over $\tilde{\Delta}_i$ gives $1 - D(p, \epsilon)$, and so, subtracting this integral from 1, as in equation (1.16), we obtain the analytical expression for the demand function. See the chart on the right of Figure 1.2 for a graphical illustration of this function -the area below the lower red line corresponds to the equilibrium demand for houses in this economy-.

1.6.6 Endowments, constrained households and market equilibrium

Substituting $S(p, \epsilon)$ for 1 in the supply formula (1.14), we find that every landlord will be willing to sell her extra house in period 1 for a price[59]

$$p^{max}(\epsilon) = p_1 + \frac{\epsilon(R_H - R_L)}{1 + r}.$$

Hence, the existence of a market equilibrium in which $D(p^*(\epsilon), \epsilon) = S(p^*(\epsilon), \epsilon)$ and every household is able to choose between renting or purchasing its dwelling is guaranteed by setting the minimum income in the low state of the world -the minimum income existing in this economy- to be strictly larger than this price,

$$W_{iL}^{min} > (1 + r)p^{max}(\epsilon).$$

Notice that -given R_H and R_L- this income is not unreasonably high. For the most extreme case, in which $\pi + \epsilon = 1$, $W_{iL}^{min} > R_1(1 + r) + R_H = p_{Max}$ guarantees that every agent will be able to pay for a house, even if the equilibrium price is the maximum possible. In general a lower minimum income will be sufficient to guarantee the existence of the 'standard'[60] market equilibrium, as given monotonicity of supply and demand with respect to ϵ, equilibrium will tend to be attained for levels of supply significantly below 1.

Letting house prices reach levels for which some households are constrained, which might potentially happen if the endowment of the poorest agent in the low state is $W_{iL}^{min} \in (R_1(1+r)+R_L, (R_1(1+r)+R_H)$,[61] does not have any surprising implication. Some households are forced to rent in both periods as the price goes over their income in the low state. The equilibrium would have a lower amount of houses traded in period 1 and a lower price than without constrained households, but the stronger

[59] Notice that for the maximum possible value of $\epsilon = 1-\pi$, $p^{max}(\epsilon)$ is just p_{Max}, the price accepted by an absolutely optimistic landlord who thinks that state H will happen with probability 1.

[60] Standard in the sense that supply and demand coincide.

[61] It is assumed that $W_{iL} > R_1(1 + r) + R_L$ and $W_{iH} > R_1(1 + r) + R_H$ so every agent is able to rent a house in both periods independently of the state of the world realized.

-more negative- decrease of demand for an increase in the price $\partial D/\partial p$ would only imply that $dp^*(\epsilon)/d\epsilon$ is lower as p increases over some threshold, remaining strictly larger than zero for any possible price —see appendix 1.6.9.

1.6.7 Proofs: monotonicity of demand and supply wrt to p

Monotonicity of supply

The monotonicity of supply with respect to p -note that ϵ does not change with p as it is just a parameter- follows trivially from the analytical expression for the supply function

$$S(p,\epsilon) = \frac{(1+r)(p-p_1)}{\epsilon(R_H,R_L)},$$

clearly

$$\frac{dS}{dp} = \frac{(1+r)p}{\epsilon(R_H-R_L)} > 0.$$

Monotonicity of demand

From the definition of the subjective expected gain in utility from buying over renting

$$\tilde{U}_i(p,\epsilon) = (\pi+\alpha_i\epsilon)U(c_{iH}^B)+(1-\pi-\alpha_i\epsilon)U(c_{iH}^B)-(\pi+\alpha_i\epsilon)U(c_{iH}^R)-(1-\pi-\alpha_i\epsilon)U(c_{iL}^R),$$

it follows

$$\frac{d\tilde{U}_i(p,\epsilon)}{dp} = (\pi+\alpha_i\epsilon)\left(\frac{\partial\left(U(c_{iH}^R)-U(c_{iH}^R)\right)}{\partial p}\right) = (\pi+\alpha_i\epsilon)(1+r)\left(U'(c_{iH}^B)-U'(c_{iH}^R)\right) < 0.$$

since given $U''(\cdot) < 0$, $U'(c_{iH}^B) - U'(c_{iH}^R) < 0$.

1.6.8 Proofs: monotonicity of demand and supply wrt ϵ

Monotonicity of supply.

The monotonicity of supply with respect to ϵ -keeping price fixed- follows directly from the monotonicity of the perceived fair price, defined as:

$$\hat{p}_j(\alpha_j,\epsilon) = R_1 + \frac{(\pi+\alpha_j\epsilon)R_H + (1-\pi-\alpha_j\epsilon)R_L}{1+r}.$$

Then,

$$\frac{d\hat{p}_j(\alpha_j,\epsilon)}{d\epsilon} = \frac{\alpha_j(R_H-R_L)}{1+r} > 0.$$

Since the subjectively perceived fair price for a house strictly increases with ϵ for every landlord, supply at a given price is monotonically decreasing on ϵ -as long as $S(p(\epsilon),\epsilon) > 0$, trivially-. This is clear from equation (1.14).

Monotonicity of demand.

From the definition of the subjective expected gain in utility from buying over renting

$$\tilde{U}_i(p,\epsilon) = (\pi+\alpha_i\epsilon)U(c^B_{iH})+(1-\pi-\alpha_i\epsilon)U(c^B_{iH})-(\pi+\alpha_i\epsilon)U(c^R_{iH})-(1-\pi-\alpha_i\epsilon)U(c^R_{iL}),$$

it follows

$$\frac{\partial\tilde{U}_i(p,\epsilon)}{\partial\epsilon} = \alpha_i\left(U(c^B_{iH}) - U(c^B_{iL}) - U(c^R_{iH}) + U(c^R_{iL})\right) > 0,$$

for every i, since we know that $U(c^B_{iH}) \geq U(C^B_{iL})$ and this holds with equality only for i such that $W_{iL} = W_{iH} = \overline{W}$; and $U(c^R_{iL}) \geq U(c_{iL}B)$, and this holds with equality only for i such that $W_{iH} - W_{iL} = R_H - R_L$. Preference for buying over renting increasing on ϵ for every household i directly implies that demand is monotonically increasing on this parameter -as long as $D(p(\epsilon),\epsilon) < 1$, trivially-.

1.6.9 Proof for the monotonicity of $p^*(\epsilon)$ wrt ϵ

Given the functions $p(D,S)$, $D(p,\epsilon)$ and $S(p,\epsilon)$ we want to show:

$$\frac{dp^*(\epsilon)}{d\epsilon} > 0 \quad \forall\ \epsilon, \tag{1.20}$$

with

$$\frac{dp^*(\epsilon)}{d\epsilon} = \frac{\partial p}{\partial D}\frac{dD}{d\epsilon} + \frac{\partial p}{\partial S}\frac{dS}{d\epsilon},$$

where

$\frac{dD}{d\epsilon} = \frac{\partial D}{\partial\epsilon} + \frac{\partial D}{\partial p}\frac{dp^*(\epsilon)}{d\epsilon}$, and $\frac{dS}{d\epsilon} = \frac{\partial S}{\partial\epsilon} + \frac{\partial S}{\partial p}\frac{dp^*(\epsilon)}{d\epsilon}$.

Then

$$\frac{dp^*(\epsilon)}{d\epsilon} = \frac{\partial p}{\partial D}\left(\frac{\partial D}{\partial\epsilon} + \frac{\partial D}{\partial p}\frac{dp^*(\epsilon)}{d\epsilon}\right) + \frac{\partial p}{\partial S}\left(\frac{\partial S}{\partial\epsilon} + \frac{\partial S}{\partial p}\frac{dp^*(\epsilon)}{d\epsilon}\right),$$

and grouping terms on $dp^*(\epsilon)/d\epsilon$ we get

$$\frac{dp^*(\epsilon)}{d\epsilon} = \frac{\frac{\partial p}{\partial D}\frac{\partial D}{\partial\epsilon} + \frac{\partial p}{\partial S}\frac{\partial S}{\partial\epsilon}}{1 - \frac{\partial p}{\partial D}\frac{\partial D}{\partial p} - \frac{\partial p}{\partial S}\frac{\partial S}{\partial p}} > 0,$$

since both the numerator and the denominator are strictly positive.[62]

[62] If the denominator being positive seems counter-intuitive to the reader, notice that it has been shown that $\partial p/\partial D > 0$ while $\partial D/\partial p < 0$, and similarly $\partial p/\partial S < 0$ while $\partial S/\partial p > 0$. In this case, the product of partial derivatives of inverse functions is not equal to 1.

1.6.10 Endogenous second period prices

The model with biased information affecting both households and landlords is extended by assuming that changes in the current price p affect second period prices, which become $R_H(p)$ and $R_L(p)$.[63] As we have seen, introducing biased information - for the case $\epsilon > 0$ - makes the equilibrium price larger than p_1, so those households choosing to buy are transferring more wealth to the supply size of the market than in the scenario with the correct expectations. In a general equilibrium framework this would affect both second period prices and income. Here, focusing on the relation between heterogeneous expectations and house prices, it is assumed that households' income distribution is not affected by a change in p, while second period prices do change.

The analysis focuses on the most significant case in this context, with $R_H(p)$ and $R_L(p)$ respectively being increasing and decreasing functions of p. The reason to choose this concrete case is the following: when state H is realized, house prices increase, and in the context of a continuing economic boom, higher prices in period 1 are translated into higher prices in period 2. If state L is realized, decreasing house prices are associated with an economic downturn, which is deeper the higher prices have previously increased. This is parallel to the information circulating across society during the Spanish housing bubble, when those predicting high prices in the future were using current inflation as a central argument to support their claim, while those warning about the risks of the bubble considered these risks to be higher the more house prices inflated.

Among the many issues that could potentially be studied in this extended model, the analysis here focuses mainly on whether the effect of heterogeneity of expectations on the decision to buy a house in period 1 is robust to endogenizing second period prices.

The first result is that for a given $\tilde{\Delta}_i$ and any price p, for any households i and j such that $\alpha_i > \alpha_j$, the increase in preference for buying over renting derived from a rise in p is larger for the worse-informed household i than for the better-informed j:

$$\frac{d\tilde{U}_i}{dp} - \frac{d\tilde{U}_j}{dp} = (1+r)\left(\frac{q_j}{c^B_{jH}} - \frac{q_i}{c^B_{iH}} + \frac{1-q_j}{c^B_{jL}} - \frac{1-q_i}{c^B_{iL}}\right) + \left(\frac{1-q_i}{c^R_{iL}} - \frac{1-q_j}{c^R_{jL}}\right)\frac{dR_L}{dp} + \left(\frac{q_i}{c^R_{iH}} - \frac{q_j}{c^R_{jH}}\right)\frac{dR_H}{dp} > 0,$$

as the three terms in the equation are positive, given $R'_H(p) > 0$ and $R'_L(p) < 0$.[64] Interpretation is straightforward, - always taking the case $\epsilon > 0$ - following an increase in prices, the preference for buying over renting increases more for those households who are more over-optimistic. Equivalently, preference for renting increases more for those who are better informed. This result indicates that under endogenous prices, an increase in price reinforces the effect of heterogeneous expectations on the decision to purchase a house, as compared to the scenario with exogenous prices.

The second result is closely related to the previous one, and says that for given $\tilde{\Delta}_i$ and any price p, for $\alpha_i > \alpha_j$ the increase in preference for buying over renting

[63] All the previous expressions still apply, the only change required is to substitute R_L and R_H by $R_L(p)$ and $R_H(p)$.

[64] This formula uses $U(\cdot) = ln(\cdot)$. The result holds for any increasing and concave utility function.

derived from a higher ϵ is larger for the worse-informed household i than for the better-informed j:

$$\frac{d\tilde{U}_i}{d\epsilon} - \frac{d\tilde{U}_j}{d\epsilon} = \left(\frac{d\tilde{U}_i}{dp} - \frac{d\tilde{U}_j}{dp}\right)\frac{dp}{d\epsilon} \geq 0,$$

with the inequality being strict whenever $dp/d\epsilon > 0$ and equal to zero when $dp/d\epsilon = 0$. Hence, whenever $dp/d\epsilon \geq 0$ holds, the effect of heterogeneity of expectations on the decision of purchasing a house in times of a housing bubble is robust to endogenizing second period prices. The difference in preference for buying over renting between relatively worse and relatively better informed households either increases or remains the same, as compared with the case under exogenous second period prices.

Equilibrium price p^* being increasing on ϵ, requires existence and uniqueness of the market equilibrium in period 1. The main challenge for supply and demand to take the same value under endogenous prices is that a very high dR_H/dp will make - at least some - households increase preference for buying when p increases, as they understand prices are more likely to be high in the future the more they increase in the present.[65] The same mechanism makes landlords less willing to sell in the first period, given a higher expected price in the future. The following analysis shows that assuming linearity of $R_H(p)$ and $R_L(p)$ and non-constrained households, there might be two different equilibria:

1. For $\lambda \leq \lambda^*$ there will be a standard, unique, equilibrium with $S(p, R_H, R_L, \epsilon) = D(p, R_H, R_L, \epsilon)$, and $dp/d\epsilon > 0$.
2. For $\lambda > \lambda^*$ there will be a 'degenerate' equilibrium in which $D(p) > S(p)$, $p = p_{max}$ the maximum feasible price, and $dp/d\epsilon = 0$. There are more households wanting to buy than landlords choosing to sell, so price is established at its maximum feasible price, and some households are forced to rent in the first period.

It is assumed that second period prices are linear functions of the price p:

$$R_H(p) = R_{H0} + \lambda(p - p_1), \tag{1.21}$$

$$R_L(p) = R_{L0} + \gamma(p - p_1), \tag{1.22}$$

where R_{H0} and R_{L0} are the parameters previously called R_H and R_L, $\lambda \geq 0$, and $\gamma \leq 0$. Notice that given $\epsilon > 0$ - what implies $S(p_1) < D(p_1)$ - these functional forms directly imply $R_H(p_1) = R_{H0}$, $R_L(p_1) = R_{L0}$, and $p_{min} = p_1$.

Let us define the minimum income in this economy to be

$$W_{iL}^{min} = R_1(1 + r) + R_{L0} + \varphi. \tag{1.23}$$

Then, for every household to be able to afford renting or buying a house in every period and every state of the world, prices must satisfy the following conditions:

[65] This is consistent with a relatively common response in García-Montalvo's survey about the reasons to purchase a house during the Spanish housing bubble 'If I do not buy now I will not be able to buy in the future'.

- Houses price in period 1 is bounded to belong to the interval $p \in [p_1, p_{max})$, where p_{max} is determined such that every household can buy a house in period 1,

$$p_{max} = \frac{W_{iL}^{min}}{1+r}. \tag{1.24}$$

- Houses second period price in state L is determined such that $R_L(p) \geq 0$, what directly implies

$$\gamma \geq \gamma^f = \frac{-R_{L0}}{p_{max} - p_1}, \tag{1.25}$$

  and so $R_L(p) \in [0, R_{L0}]$ and $\gamma \in [\gamma^f, 0]$. f stands for feasible.

- Houses second period price in state H is determined such that every agent can rent a house both in the first and the second period, even if state H is realized. This requires $R_H(p) < R_H^{max}(p) = W_{iH}^{min} = W_{iL}^{min} + \pi(R_{H0} - R_{L0})$. Then

$$\lambda < \lambda^f = \frac{\varphi - (1-\pi)(R_{H0} - R_{L0})}{p_{max} - p_1}, \tag{1.26}$$

  and so, $R_H(p) \in [0, R_H^{max}(p))$ and $\lambda \in [0, \lambda^f)$. Notice that $p_{max} - p_1 = \varphi - \pi(R_{H0} - R_{L0})$.

With $R_H(p)$ and $R_L(p)$ being linear functions of p as given by equations (1.21) and (1.22), and with parameters belonging to the intervals defined above, such that no household is constrained when choosing its tenure choice, the equilibrium prices $p^*(\epsilon, R_H, R_L)$, $R_H^*(p)$, and $R_L^*(p)$ that clear the housing market exist. It can be shown that for a large enough income, the value of λ which makes $S(p_{max}) = 1$ is larger than the maximum feasible λ^f. This guarantees existence of the standard equilibrium.

Uniqueness of the standard equilibrium is not easy to show analytically. Weakly monotonicity of supply with respect to p and ϵ is easy to show, in the same way as in the case of exogenous second period prices, as it holds for every landlord. However, increasing preference for buying as p increases does not hold for every household. For λ very close to λ^f, those households who prefer buying the most - low $\tilde{\Delta}_i$ and high α_i - will see their preference for buying increased as the price p increases. Intuitively, this should not be a big problem, as most of these households already prefer to buy at the low price p_1, and so their increase in willingness to buy as the price rises should not compensate for the decrease in the willingness to buy of the rest of the population, but the fact that the demand function is not solvable analytically - as the integral in equation (1.16)[66] is not - makes it necessary to use numerical methods.

Solving the problem numerically, it is found that for feasible values of λ, γ, p and a large enough income, the standard equilibrium is obtained. See the left hand side in Figure 1.4.

[66] The only change in this equation implied by endogenous prices is to substitute R_H and R_L by $R_H(p)$ and $R_L(p)$ in the definition of consumption in equation (1.17).

This 'large enough income' is concretely:

$$\varphi \geq \varphi^* = \frac{(R_{H0} - R_{L0})\left[\pi(1+r)(\pi+\epsilon) - (1-\pi-\epsilon)\gamma\pi\right]}{(1+r)(1-(\pi+\epsilon)) - (1-\pi-\epsilon)\gamma}, \tag{1.27}$$

which tends to ∞ as $\pi + \epsilon$ tends to 1. If households income is not large enough as to satisfy this condition, it might be the case that the maximum feasible λ^f is smaller than the λ which guarantees $S(p_{max}) = 1$. In this case, under certain parametrizations, very large values of λ will take the economy to the 'degenerate' equilibrium, where transactions are established at the maximum feasible price p_{max} and there are more households wanting to buy in period 1 than landlords supplying houses in period 1. See the right hand side in Figure 1.4. Importantly, under any parametrization, there is always a positive proportion of relatively better informed households - those with relatively low α_i, and relatively high $\tilde{\Delta}_i$ - who prefer to rent for any feasible λ and p, so the effect of heterogeneous expectations on the decision to purchase a house in the same period still holds under endogenous second period prices.

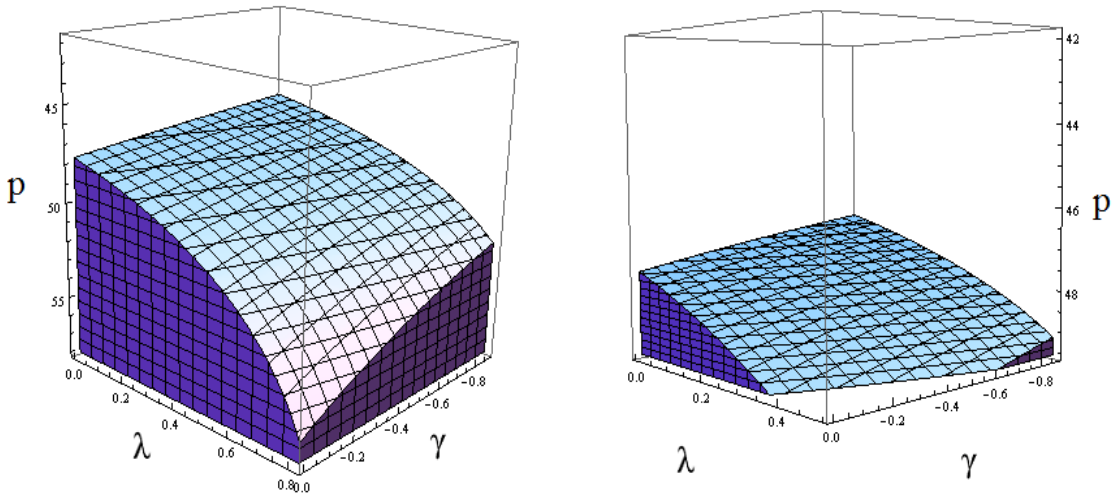

Figure 1.4 – Numerical solution for the market equilibrium, $D(p, R_H, R_L) - S(p, R_H, R_L)$ under endogenous second period prices. Both figures are done with the same parametrization, differing only on the minimum income, lower on the RHS. Reducing p_{max} and λ^f accordingly produces the two different types of equilibria.

1.6.11 Robustness checks

	(1) purchase	(2) purchase	(3) purchase
highschool (d)	0.134	-0.241***	-0.156
	(1.07)	(-2.83)	(-1.39)
university (d)	-0.0935	-0.261***	0.0533
	(-0.68)	(-4.27)	(0.37)
finance (d)	-0.0566	0.127	0.118
	(-0.43)	(0.46)	(0.62)
riskaverse (d)	0.609***	-0.209***	0.199
	(4.91)	(-4.25)	(0.63)
income	0.0867***	0.0273	-0.0334
	(3.76)	(0.86)	(-1.08)
stddev_income	-0.665***	-0.320*	0.0555
	(-3.04)	(-1.72)	(0.25)
cov_inc_price	1.77e-08*	1.44e-08	3.15e-08*
	(1.95)	(1.23)	(1.91)
controls	YES	YES	YES
Observations	193	169	263

Marginal effects; t statistics in parentheses

(d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.3 – Marginal effects, probit: explaining the decision to purchase the main dwelling for those households which do not own it by the start of the period, using *highschool* and *university* instead of *more_educ*. 1999-2002 (column 1), 2003-2005 (column 2), 2006-2008 (column 3).

	(1) purchase	(2) purchase	(3) purchase
more_educ (d)	0.0133	-0.211**	-0.0708
	(0.17)	(-2.49)	(-1.01)
finance (d)	-0.0562	0.135	0.142
	(-0.55)	(1.06)	(1.32)
riskaverse (d)	0.445***	-0.184*	-0.0598
	(2.60)	(-1.68)	(-0.43)
income	0.0244**	0.00864	-0.0165**
	(2.01)	(0.48)	(-1.97)
stddev_income	-0.334**	-0.191	0.0828
	(-2.08)	(-1.11)	(0.55)
cov_inc_price	3.08e-09	1.51e-08**	3.74e-09
	(0.52)	(2.12)	(1.04)
controls	YES	YES	YES
Observations	193	169	263

Marginal effects; t statistics in parentheses

(d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.4 – Marginal effects, probit, no probability weights: explaining the decision to purchase the main dwelling for those households which do not own it by the start of the period, using *highschool* and *university* instead of *more_educ*. 1999-2002 (column 1), 2003-2005 (column 2), 2006-2008 (column 3).

	(1) purchase	(2) purchase	(3) purchase
more_educ (d)	0.111	-0.293***	-0.0742
	(1.15)	(-3.92)	(-0.75)
finance (d)	-0.00704	0.111	0.124
	(-0.05)	(0.46)	(0.63)
riskaverse (d)	0.634***	-0.158***	0.247
	(4.94)	(-4.01)	(0.76)
income	0.0518***	0.0278	-0.0171
	(2.62)	(1.23)	(-0.64)
stddev_income	-0.305*	-0.234	0.0664
	(-1.66)	(-1.55)	(0.37)
cov_inc_price	1.03e-08	1.38e-08	2.53e-08*
controls	YES	YES	YES
Observations	222	194	320

Marginal effects; t statistics in parentheses

(d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.5 – Marginal effects, probit, including also households with a negative wealth by the start of the period: explaining the decision to purchase the main dwelling for those households which do not own it by the start of the period, using *highschool* and *university* instead of *more_educ*. 1999-2002 (column 1), 2003-2005 (column 2), 2006-2008 (column 3).

	(1) purchase	(2) purchase	(3) purchase
more_educ (d)	0.180***	-0.170**	-0.125
	(2.72)	(-2.17)	(-1.36)
finance (d)	-0.00236	-0.0437	-0.0360
	(-0.03)	(-0.30)	(-0.26)
riskaverse (d)	0.377*	-0.134	0.321*
	(1.89)	(-1.21)	(1.77)
income	0.0224	0.0280	-0.00217
	(1.48)	(1.27)	(-0.10)
stddev_income	-0.259**	0.00706	0.267
	(-2.24)	(0.05)	(1.55)
cov_inc_price	3.81e-09	-2.22e-11	1.24e-08
controls	YES	YES	YES
Observations	346	271	435

Marginal effects; t statistics in parentheses

(d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.6 – Marginal effects, probit, including also households which got their main dwelling without purchasing it at market price: explaining the decision to purchase the main dwelling for those households which do not own it by the start of the period, using *highschool* and *university* instead of *more_educ*. 1999-2002 (column 1), 2003-2005 (column 2), 2006-2008 (column 3).

	(1) purchase	(2) purchase	(3) purchase	(4) purchase
more_educ (d)	-0.0210	-0.00738	-0.0206	-0.0160
	(-1.40)	(-0.38)	(-1.23)	(-1.39)
finance (d)	0.00202	0.0128	0.0187	0.00448
	(0.11)	(0.50)	(0.94)	(0.35)
riskaverse (d)	0.0451***	0.0644**	0.0560***	0.0334**
	(3.80)	(2.18)	(3.81)	(2.25)
income	0.0143***	0.0188***	0.0150***	0.00597***
	(3.43)	(3.35)	(3.22)	(2.76)
stddev_income	-0.104***	-0.119***	-0.107***	-0.0736***
	(-3.96)	(-3.32)	(-3.58)	(-3.44)
cov_inc_price	1.97e-09	2.79e-09*	2.15e-09	8.85e-10
	(1.48)	(1.67)	(1.42)	(1.40)
controls	YES	YES	YES	YES
Observations	2036	2534	2067	2036

Marginal effects; t statistics in parentheses

(d) for discrete change of dummy variable from 0 to 1

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.7 – Marginal effects, probit: explaining the decision to purchase the main dwelling for those households which own it by 2002. Column 1: all restrictions included, column 2: including also households which did not purchase their main dwelling at market prices, column 3: including also households with negative wealth by 2002, column 4: no probability weights.

Chapter 2

Diversity, Group Size and Performance in Organizations

joint with Shan Aman-Rana.[1]

How does diversity between team members interact with group size in affecting performance? In this chapter we model both horizontal and hierarchical teams with knowledge spillovers in production and heterogeneous between-group and within-group costs of communication, comparing the expected productivity of workers in homogeneous and heterogeneous teams. The main theoretical result is that the effect of introducing a diverse worker on colleagues' performance is increasing in the size of the group or the hierarchical layer where the newcomer is allocated. This prediction is tested using a novel rich administrative data set of tax collectors in the Pakistan Administrative Services. In order to observe worker heterogeneity we exploit a policy requirement whereby 10% of the PAS civil servants have to come directly from the army. We find that working with a military colleague is associated to a larger performance for civilian civil servants the larger the layer in which the military is introduced. Based on these results, we suggest some rules for the efficient allocation of heterogeneous workers in hierarchical organizations that maximize aggregate productivity.

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2.1 Introduction

One of the main purposes of economic organizations is to coordinate the solution of the variety of tasks associated to production, in the presence of workers' heterogeneous skills and knowledge (Garicano, 2000) derived from the capacity of each individual to specialize in the solution of a limited number of problems (Hayek, 1945). When communication is available, reaching the best possible match between individuals and the problems they can solve is not enough for production efficiency. Workers allocation must be such that the organization takes the maximum advantage of the complementarity between their knowledge, while minimizing communication cots.

The economics literature has taken good account of this observation. The seminal paper on the 'organization of knowledge in production' (Garicano, 2000), sets aside incentives problems[2] to focus on the optimal number and size of layers of a hierarchical organization such that knowledge spillovers are maximized. Always in an organizational setting, several studies have focused on the relationship between workers heterogeneity (typically in terms of nationality and productivity levels) and organizational structure, exploring the idea that communication across more diverse colleagues entails a trade-off between larger knowledge spillovers and higher communication costs (Antràs et al., 2006a,b; Lazear, 1999b).[4]

With the objective of explaining globalization at an organizational level, understood as the combination of workers from different nationalities in global firms[5] and off-shoring (Antràs et al., 2006a,b; Lazear, 1999b), these papers have restricted their focus to the optimality of combining workers from different countries for the efficient structure of —global—firms. To the best of our knowledge, the literature has missed applying these same mechanisms to explain the relationship between diversity, knowledge spillovers and performance at the individual level, and to test them in an organizational setting, at the micro level. This is precisely what we do in this paper.

The current state of the literature suffers from a miss-match between the existence of powerful theoretical models relating diversity and performance, but designed specifically to explain the structure of global firms with predictions which are then tested using cross-country empirical evidence, such as trading patterns with countries being more likely to import from countries which speak the same language (Lazear, 1999b), or the correlation between the level of off-shoring and educational attain-

[2] A good understanding about many important economic problems has resulted from the incentives based approach to organization problems, in particular in relation to wages, effort and hierarchical layer size (see Mirrlees, 1976; Calvo and Wellisz, 1979; Qian, 1994).[3] However, the incentive-based approach cannot say much about certain problems related to information and communication, such as in which position will a given worker's knowledge spillovers to the rest of the team be maximized.

[4] Interesting mechanisms explaining the impact of —ethnic—diversity on economic and policy outcomes (Alesina and La Ferrara, 2005) or group participation (Alesina and La Ferrara, 2000) have also been studied out of an organizational setting.

[5] Similar models have been used to illustrate other processes related to globalization, such as the possible gains from immigration, associated to the increasing diversity of skills in the population (Lazear, 2000) or cultural and linguistic assimilation (Lazear, 1999a) and the associated social gains.

ment at the country level (Antràs et al., 2006b),[6] and empirical studies which have directly[7] studied the relationship between diversity in groups and performance with very interesting and well identified causal effects, (e.g. Hoxby, 2000; Hansen et al., 2006; Gagliarducci and Paserman, 2011), but either lacking an explicit mechanism or theoretical model supporting their rich findings, or focusing on the effect of different kinds of diversity (gender, age, race) on performance while ignoring the way in which this effect is mediated by certain factors, in particular group size.

Supporting findings related to the relationship between group diversity and performance with a general framework is crucial to understand why do the positive or the negative effects of increasing group diversity dominate in a given context. In order to formalize the kind of interaction effects we expect to find between group size and diversity we develop a theoretical model. The basic set-up from Lazear 1999b is modified such that knowledge spillovers affect not only aggregate group performance but also individual performance. This is probably the main twist to the model, as it allows us to study in detail how different group compositions affect the performance of individual team members as, as a function of their type. The cost of communication is interpreted as time far from the production process, similarly to the interpretation in Garicano 2000. We first explore the simplest version of the model, with homogeneous teams. With the introduction of heterogeneous workers into the model, the cost of communication is higher for workers of different types, as in Antràs et al. 2006b. In order to increase the explanatory capacity and versatility of the model and to derive richer predictions for our case study, this is extended to a hierarchical structure with several interconnected layers. Importantly, several predictions are qualitatively different for horizontal and hierarchical groups, both for the case of homogeneous and heterogeneous organizations, making the study of hierarchy insightful by itself.

The main prediction from the model relates group size (or layer size in the case of hierarchical groups) and the trade-off between the higher knowledge spillovers and communication costs associated to diversity. While present in previous studies (e.g. Lazear, 1999b) this part of the mechanism has in our view not received the deserved attention (either in theoretical or empirical papers): the marginal contribution of an extra type 1 worker to the productivity of her same-type colleagues should be decreasing on their number, as its knowledge and skills become redundant. This implies that everything else equal, the change in productivity from substituting a type 1 colleague by a type 2 one will be increasing in the number of type 1 workers in the group.[8]

[6] To the best of our knowledge, in those papers studying ethnic diversity, migration, or cultural assimilation, the suggested mechanisms are tested either at the cross-country, national, the regional or the municipal level, but never in relatively small groups such as an organization's teams.

[7] While any effect of group diversity on performance can be rightly considered as a peer effect, there is a remarkable difference between studies directly focusing on diversity and 'traditional' peer effects studies: the peer effects literature has focused on how certain agents influence others into behaving more similarly to them, while 'pure' studies of group diversity depart from ordering workers in any dimension related to performance or behavior, focusing instead on the potential that the existence of heterogeneous workers in the same group opens for the complementarity of skills to kick in. The empirical literature on traditional peer effects is rich and large (e.g. Sacerdote, 2001; Zimmerman, 2003; Falk and Ichino, 2006; Mas and Moretti, 2009; Powell et al., 2005; Ichino and Maggi, 2000; Campos et al., 2016; Sacerdote, 2001).

[8] For the case of homogeneous groups composed by type 1 workers, the effect of such a substi-

The model is tested in a public sector context, explaining the performance of Pakistan tax collectors. We use a novel and rich administrative data-set from the Pakistan Administrative Services (PAS) with monthly-frequency observations on the placement and performance of tax collectors and other civil servants in Punjab between 1987 and 2013. This context has several advantages. First of all, a policy requirement whereby 10% of the PAS must come from the army offers a particularly salient criterion for the definition of diversity,[9] allowing us to clearly divide our sample into two different types of workers: civilians will be the type 1 workers, and the military civil servants the type 2 ones. Secondly, as we will see in more detail, collecting taxes in Pakistan entails a huge number of skills to solve a large variety of complex tasks, for which none single worker can be fully equipped, creating the space for knowledge spillovers to impact production. Importantly, the available information about the amount of taxes collected over the established target offers an individual quantitative measure of performance, not always available or even easy to define for many complex problems. Two factors which facilitate the study from a technical point of view are the large number of groups and the important variability in their size, and the unequal distribution of types, with a vast majority of civilian workers and a small proportion of military ones. Finally, as we will see the distribution of workers within groups is such that it is easy to define a hierarchical structure for them, which will allow us to test the model at different levels, increasing both the explanatory capacity of the model and the robustness of the empirical findings.

A regression analysis of tax collectors' performance explained by group composition offers descriptive evidence coherent with the main predictions from the theoretical model, both for the case of homogeneous and heterogeneous groups, and for the case of horizontal and hierarchical groups —see figure 2.2 in appendix 2.7.1 for an illustrative example of a typical hierarchical team considered in this paper, as will be explained in detail later. For the latter, the predictions from the model hold across and within layers.[10]

tution will be just increasing in group size.

[9]Every study we read about military life (see section 2.2.2) emphasizes how both selection and experience should make the average military significantly different from the average civilian worker. Probably the most relevant reference supporting that military and civilian workers should be different in relevant aspects for this study is given by Akerlof and Kranton 2005. The authors choose precisely these two different categories of workers to illustrate how identity might be an important factor determining performance, after putting forward solid arguments and references in favor of the military as a salient social category which should matter significantly in any organizational setting. In which ways should we expect the military and the civilian to be and behave differently, and why should these matter for performance in the context of the Pakistan public administration is analyzed in detail in section 2.2.2.

[10]Controlling for the work environment, the period, and individual characteristics, having a military colleague in the smallest layer is associated with a lower performance for civilian tax collectors, as those having a military supervisor perform worse than when their supervisor is of their same type. Having a military colleague in the mid or larger layers is in average not associated with either a higher or a lower performance than when these layers are fully homogeneous. This average effect does not tell the whole story though, as predicted by the suggested mechanism, there are important within-layer differences: those workers having a military colleague in a given layer tend to perform better when the number of workers in that layer is larger. This is true both for the layer of tax collectors and for the largest, bottom layer composed by 'other workers' —. As predicted by the simple model with homogeneous teams, having a higher number of same-type colleagues is associated with a higher performance, at a decreasing rate. This is found to hold both for the total number of colleagues in the same group and for the number of colleagues in each

Finally, the formalization of the proposed mechanism into a theoretical model has the advantage of allowing us to provide some rules for the optimal allocation of workers into teams, from the point of view of an organization maximizing aggregate production net of workers' wages. These results will allow for an increase of production just rotating workers across teams, without increasing labour costs.

By narrowing the gap between theory and evidence in studies of diversity and performance in organizational settings, the contribution of this paper is two-fold. On the one hand, the adaptation of a sound theoretical mechanism for group dynamics to explain also individual performance and the detailed focus on the effects of group composition, offers a simple but general framework to orientate the empirical study of diversity in teams.[11] On the other hand, showing evidence on the main mechanism proposed by the seminal papers on the composition of global firms being at play at the micro level in an organizational setting, should serve as support for their theses, reinforcing the validity of their findings.

The paper is organized as follows: Section 2 we describes in detail the field situation and the institutional background in the Pakistan Administrative Services. Section 3 develops the theoretical model, both for the cases of horizontal and hierarchical groups, deriving the hypotheses about individual performance to be tested in the empirical part of the paper. In Section 4 we describe the data, including our measure of performance and the targets for tax collection, the empirical models used to test the corresponding hypotheses, and report the main findings. Section 5 explores how the mechanism developed and tested in the previous sections can be used to design rules for an optimal allocation of workers. Section 6 concludes.

2.2 Institutional background: collecting taxes in Punjab

In this section we describe the main elements of the field situation. This should help the reader to understand the meaning of the main elements from the theoretical model in an organizational setting, such as the kind of knowledge spillovers which might be at play, or the motivation behind the definition of workers' types, and their distribution into the group's hierarchical layers.

of the two layers with more than one worker.

[11] This makes the paper also relevant for organizational researchers from the disciplines of management, sociology and social psychology, in which the study of this question has a very long and prolific tradition. While the work in these fields has found broad evidence on the existence of a direct relationship between group diversity and performance (see Pelled et al., 1999; Williams and O'Reilly III, 1998, for two extensive reviews of the literature classifying how different kinds of group heterogeneity (e.g. gender, race, age, nationality, etc.) tend to affect team performance in one or another direction), the lack of a theoretical mechanism supporting their rich findings is arguably a weakness in most of these studies. A notable exception to this pattern is given by Smith 2014. While this paper does not develop a formal model, the similarity between the predictions they derive from the concept of 'redundant heterogeneity' and those resulting from our hierarchical model are remarkable.

2.2.1 The Assistant Commissioners in the Civil Services of Pakistan

This paper studies tax collection in the province of Punjab, which with over 100 million of inhabitants by 2015 contains more than half of the total population in the country. Punjab province is divided into 36 districts and each of these districts is sub-divided into a number of teshils ranging between 2 and 7, for a total of 141.[12] We start by describing the tasks of the main agents in this study: Punjab Assistant Commissioners (ACs), the civil servants in charge of administration and responsible for tax collection at the tehsil level, and the environment in which they operate.

Who they are and how they are selected

The civil servants working in the Punjab belong either to the Provincial Management Services (PMS), or the Pakistan Administrative Services (PAS).[13] Civil servants who become part of any of these bodies are selected through highly competitive exams,[14] and after a period of training are typically placed as the Assistant Commissioner for a tehsil.[15] While there are some differences between the two services in terms of career prospects,[16] in their position as ACs all of them enjoy the exact same conditions, independently of the service they belong to. For the object of this study, the only relevant difference between these two services is that all the military will be inducted as PAS. In concrete a quota of 10% of the PAS positions is allocated to the military.

The tasks and responsibilities of ACs

Assistant Commissioners head the revenue administration in tehsils in Punjab. According to the official description of their role, they are the maximum authority in relation to the 'general management, administration of the State land, revenue matters, and coordination between the government departments' in the tehsil they direct.

[12]These teshils are somehow the equivalent of —large—European municipalities or councils.

[13]Officially, before 2004 those civil servants who were not part of the PAS were part of either the Provincial Secretariat Services (PSS) or the Provincial Civil Service (PCS). With the introduction of the PMS Rules in 2004, PMS was created and there was no further hiring under Provincial Secretariat Services (PSS) or Provincial Civil Service (PCS). These services were to be called ex-PCS and ex-PSS and came under the same rules as PMS.

[14]Those workers in the Pakistan Administrative Services (PAS) are selected at the national level, with 35 to 40 PAS officers inducted every year from a pool of candidates which typically ranges between 24,000 and 26,000, while the rest are provincially recruited through an exam held by the Punjab Public Service Commission. Workers in both services receive an approximately one-year long training after selection, which includes a 22-weeks 'field attachment within a district', after which they become level 17 officers (all civil servants start their careers in grade 17, with the maximum grade being 22).

[15]There is not a clear set of rules or criteria for this allocation, which cannot be considered random either.

[16]For example PMS can only serve in the province where they took the exam, while PAS can serve in the whole country.

Over the years, many different legal and civil services reforms have resulted in a change in the role played by ACs (see appendix 2.7.2 for a description of the main functions of ACs in the province of Punjab under the different regulatory regimes). Importantly, across all reforms revenue administration has always remained as a core duty for Assistant Commissioners. Fortunately for this study, the administrative data collected by the Pakistani Administrative Services contains a quantitative measure of the amount of taxes collected in a given tehsil in a given month, over the centrally established annual objective. Given the centrality of revenue administration among an AC responsibilities, this measure of performance should be an adequate indicator of the degree to which a given AC is doing 'a good job'.[17]

The Role of ACs in Tax Collection

The main responsibilities of an AC with regards to revenue administration are to recruit the lower revenue field staff, to monitor their progress, periodically checking their revenue record, and to report the outcome to higher authorities. Hence, in practice every Assistant Commissioner is the manager of a relatively large team of workers whose main duties are land administration and collecting taxes from agricultural producers.[18]

The coordination of a relatively large team and the successful solution of the tasks associated to this position requires the AC to master a diverse set of skills, such as understanding which job-categories require a certain expertise, assessing the need for qualified personnel addressing the gaps in capacity, having a broad vision and understanding of the overall system they are supervising, a relatively good knowledge of the territory to which they are allocated, planning control and accountability mechanisms, keeping a right monitoring system, contributing and pushing her subordinates towards an organizational culture which encourages the sharing of values and ideas which contribute towards a good performance, making sure that her supervisees receive structured and clear mandates, or staying updated about legal and regulatory changes, or technical developments, just to name a few —see Enemark and Van der Molen 2008 for a systematic analysis of the main factors relating workers capacity and an effective land administration.

On top of the long list of complex tasks and skills required from a successful Assistant Commissioner, some institutional particularities of tax collection in Pakistan, such as the corruption of lower revenue officials, complicate their work even further.[19]

[17] The nature of the available measure of performance is carefully described in section 2.4.1.

[18] The team supervised by the AC is composed of 'Patwaris', 'Naib-tehsildars' and 'Tehsildars', all of whom are in general referred to as revenue officers. The 'Patwari' (grade 5) or 'village accountant' is the official at the lowest rung of the revenue collection machinery. His job encompasses visiting agricultural lands and maintaining a record of ownership and tilling, with their jurisdiction typically spanning a couple of villages grouped together to form a 'Patwar' circle. The 'Naib-Tehsildar' is the supervisory tier for a team of 'Patwaris' and is generally a grade 14 official. There is one or two designated 'Tehsildars' in tehsils and depending on their seniority are generally a grade 16/17 official.

[19] In particular, the position of 'Patwaris' as the maximum authority for land titling in the corresponding 'Patwar circle' and their important role in tax collection in rural areas where literacy and wealth is low, tends to give these officials a large influence on local communities. This makes them particularly prone to corruption, with practices such as demanding bribes and changing land

Can the skills, knowledge and behavior of the Assistant Commissioner make any difference to the aggregate tax collected in the tehsil she administrates? Since our data covers performance at the tehsil level, without any information on the lower revenue officers supervised by the corresponding AC, a positive answer to this question is required in order to expect any kind of results from a study relating ACs' characteristics and conditions with their performance as tax collectors.

The results of a recent study by (Bertrand et al., 2016) in a somehow similar context, which relates elite civil servants who enter Indian state cadres older and in larger cohorts with a lower effectiveness, and this to a lower aggregate economic performance in the states where they are placed, points towards the behavior of elite civil servants being potentially significant for aggregate outcomes.

As we will see, our results will also indicate that the characteristics and environment of an AC, and in particular the number and type of elite[20] civil servants in their same district matter.

Other elite civil servants in the district and the performance of ACs

As mentioned before, each of the 141 tehsils in Punjab is an administrative subdivision of one of its 36 provincial districts. This implies that each of the Assistant Commissioners who manages a tehsil has a frequent and direct professional relationship with those elite civil servants posted in her same district at the same time. While we do not have data on the workers the AC supervises, we do have data on the elite colleagues in the same district, who perform a variety of heterogeneous jobs. Before describing the different roles of these workers, it seems necessary to reflect for a moment about their potential impact of on our question of interest: the performance of an AC in their same district.

On the one hand, the Assistant Commissioner is the maximum authority for tax collection in the tehsil where she is posted, and manages her team of revenue officers pretty independently. High-powered incentives are relatively scarce in this public sector setting, as civil servants cannot be fired, and salary depends to a large extent on seniority, reducing to a certain extent the pressure or control that other colleagues, such as supervisors, might place on the work of an AC.[21] This autonomy of action supports skepticism towards the degree to which any colleagues apart from those supervised by the AC might influence her performance.

records at will being considered endemic to the post. The perception of widespread corruption and inefficiency among Punjab 'Patwaris' is studied in a series of publications related to the Land Record Management Information System (LRMIS) project for the computerization of land records in this province, designed to solve some of the most acute historical problems related to land administration in this territory. This project was co-financed with 52 $\$US$-million and co-supervised by the World Bank, and was finished on the 31st of December of 2016, after starting in 2007, see (Deininger et al., 2001; Qazi, 2005, 2006). The data in our study correspond to the period before computerized land records became functional.

[20] In this context, by 'elite civil servants' we refer to those civil servants over grade 17, members of the PAS or the PMS. These category does not include the revenue officers supervised by the AC ('Patwaris', 'Naib-tehsildars' nor 'Tehsildars'), for whom data is not available.

[21] Promotions is an aspect which should be explored in depth, as a possible means of influence on an AC's behavior.

On the other hand, we have seen that the Assistant Commissioner has to solve a huge number of complex tasks in order to fulfill her daily responsibilities. Can she know the optimal solution to each of the challenges she faces? Probably not. This makes those elite civil servants with whom the AC has a frequent contact a possible asset in terms of knowledge and skills, as one would expect each of them to have some expertise on at least part of the issues the AC might struggle with or just not be sure about.[22]

Basically, one can think about the taxes collected in a given tehsil in a certain month as the output of a production function corresponding to a process managed by the AC. The information content of this function opens the space for colleagues who do not directly work on tax collection in the same tehsil but with whom the AC communicates frequently, to have an impact on her performance through knowledge spillovers, potentially influencing the amount of tax she collects in a given period. Some of examples of relevant and transferable knowledge might include a higher familiarity with the territory or the population in the AC's tehsil, personally knowing some of the AC's supervisees, land-owners or other people relevant for tax collection in the community; having faced a challenge similar to that the AC is currently facing, for example previous experience with complicated situations related to the management of human resources, such as incentivizing a un-motivated colleague, or dealing with a supervisee who is suspected corrupt; or expertise with developing good organizational practices such as scheduling functional and effective meetings, or improving the planning of the main objectives to be completed during the corresponding financial year.

Whether and how the number, position and type of the rest of workers in the district influences the performance of the AC in collecting taxes is the main object of this paper.

The other elite civil servants in the district: defining the AC's group

How does communication across colleagues matter if it matters? The autonomy and authority of the AC in those issues related with the administration of her tehsil implies that after asking other civil servants for advise, she has always the last say in choosing the action she considers better suited for solving the task at hand.

The AC's autonomy to choose her preferred action is important in this setting for two reasons. First, because a group is defined in this context by social, geographical and professional proximity —which arguably results in ease of communication—, and not by a common objective or task, as the Assistant Commissioner's objectives remain mainly as her personal competency. This has the advantage of making it unnecessary a long discussion about the nature of the different tasks the group faces and their relative relevance here.[23] Secondly, because as long as we assume that ACs are better than random at choosing the best option when presented with several alternative solutions, we can just assume that having more information is

[22] See for example Rodan and Galunic 2004 for evidence on the positive association between managers' access to knowledge heterogeneity and their individual performance.

[23] For a classification of kinds of tasks in group environments, in categories such as disjunctive or conjunctive, intellective, criterion or judgmental, maximizing, etc, see for example (Steiner, 2007).

always weakly better for an AC's performance than having less information. This, together with ACs preferring to do better than worse for the same amount of effort, is all we need for our suggested mechanism to work.

Following the criterion of a high enough expected communication frequency among team members, a group is defined to be composed by all those elite civil servants working at the same district at the same time. Focusing on the relationship between these different workers and tax collectors (ACs), the group is divided in three different layers:[24]

- Layer 1: This uni-personal layer is composed by the direct supervisor of all the ACs in the corresponding district, the Deputy Commissioner (DC). This is the most obvious professional relationship for the AC, and so in principle the one with the highest potential to affect her performance. In accordance with her supervisory role, each district's DC and ACs have a monthly joint meeting with the explicit objective of discussing the progress made in each of the tehsils managed by the corresponding AC. The objective of these meetings is to discuss the main challenges each AC is facing, and to look for potential ways of improving the efficiency and efficacy in the administration of their respective tehsil. Naturally, as tax collection is one of the main tasks of ACs, its improvement and monitoring is a central issue in these meetings.[25]

- Layer 2: This layer is composed by the Assistant Commissioners in the district, with their number ranging between 1 and 7 as corresponds to the number of tehsils in each district, plus the existence of vacant positions in certain periods. The monthly meetings in which they participate together with the DC guarantee that ACs in the same district communicate among themselves frequently, and typically get to know each other relatively well. While it is not immediate that ACs establish collaborative communication among themselves, the similarity in the responsibilities, the challenges and the tasks they face, together with the frequency of their meetings and their geographic proximity, give their relationships a significant potential for knowledge spillovers.

- Layer 3: The third layer, typically the most populated, is composed by the 'other workers' in the district: those elite civil servants which are not DCs or ACs. These work in different departments of the public administration instead of revenue, such as district level finance, education, health etc. There are also periodic joint meetings between the ACs and these other departments.[26]. While these meetings are not directly associated with revenue administration, given the ACs functions of coordinating across departments and the geographic and institutional proximity among them, we cannot exclude the possibility of the ACs' performance being also influenced by the knowledge and expertise of these 'other workers'.

Notice that this group division in layers is based on the different relation of the

[24] Again, you can have a look at figure 2.2 in appendix 2.7.1 for an illustrative example of the structure of these groups.

[25] As we will see in section 2.4 each AC sends to the corresponding DC a monthly official communication about the amount of taxes collected.

[26] The nature of these meetings can vary, for example, with the District Finance Department there can be regular meetings surrounding budgetary allocations and utilization

workers with the ACs, and while the grade of the DC is in fact higher up in the official hierarchy of the organization than that of ACs, this is not necessarily the case for the workers in the layer 3. Similarly, the ordering of these layers is based on their average size, and is not determined by the existence of a relationship of authority or differential rank.

2.2.2 Introducing diversity: the military

In this section we motivate why having both civilian and military workers is a particularly well suited condition for the study of diversity in an organizational setting, and why this particular kind of diversity might have an effect on the performance of civilian ACs as tax collectors, in the context of Punjab civil services.

A large number of studies support that both selection and experience make the average military significantly different from the average civilian.[27] The institutional structure of the Pakistan army, which is fully based on volunteer enlistment and does not require any kind of military service for the civilian population, creates a convenient clear-cut distinction with respect to military experience between the civilian and the military workers in our sample: all those who have served in the army chose to do so, and virtually none of the civilians have undertaken any military training or had professional military experience. This should make the military and the civilian civil servants in our study different in many —potentially relevant for performance—ways.

First, we can check in our data that the average military is different from the average civilian worker in many observable aspects. Some of these differences include among others, the fact that the military join the civil services being older, are younger in average, all of them are men and a much higher proportion of them is originally from other regions, see table 2.1.

[27] A brief review of the existing evidence of disparities between values and personality traits among the military and the civilian population illustrates why one would expect these two types of workers to show significant discrepancies, with the potential to produce important differences in terms of workers' behavior, inter-personal relationships and between-type communication. Much of the existing sociological and psychological literature comparing the military with members of the civilian population agrees on the existence of a distinctive set of values and personality traits. As Bachman et al. 1987 put it *'based on much literature, there is a widespread agreement that military personnel tend to be above average in nationalism, conservatism, and traditionalism. They have also been characterized both in positive terms such as professional, patriotic, and altruistic, and in more controversial terms such as authoritarian, militaristic, and aggressive... the overall connection between service and pro-military values has been firmly enough documented so that interest now centers on* why *rather than* whether *such a connection exists.'* In short, many different sources show how self-selection, training and professional experience in the army gives the military differentiated and importantly for our study, long-lasting characteristics —see Jackson et al. 2012 for an interesting study about the long-lasting nature of personality traits acquired during the military service in Germany, with changes persisting even after individuals have entered colleague or the labor market (the study shows effects after 5 years). The direct relationship between personality traits and consequential outcomes is a well established fact —see Ozer and Benet-Martinez 2006 for a broad review on the literature on this precise question.

	Average Military	Average Civilian
Joining age (months)	383.25	353.59
Current age (months)	465	497
Women	0	0.07
No Punjabi	0.47	0.13
Number of promotions	1.09	0.30
AC	0.21	0.27
Performance (ACs)	9.59	7.689

Table 2.1 – Average values for different variables across the military and civilian workers who work in teams with some information on performance.

Secondly, the long and prolific literature on the differences between the military and the civilian suggests we should expect both types of workers to diverge significantly also in unobservable aspects. Some of these aspects should be relevant for professional performance and interpersonal communication, such as personality traits, their understanding of professional identity and organizational culture, and consequently their behavior at work.

Our study is limited to the analysis of the effects on individual performance of combining in the same group workers who are different enough as to be characterized as two different types. The only conditions the definition of types must satisfy for our suggested mechanism to work, is that both the diversity of —relevant—knowledge and the costs of communication must in average be higher across the defined categories than within same-type workers.

Given this lax criterion for the adequate distribution of workers into two different types, the differences in observable characteristics, together with the unobservable attributes we would expect to exist between them, should be enough for us to consider the civilian and the military as two different categories of workers. The best test is, naturally, to see if the way they are combined into groups affects their individual performances in any measurable way.

In the next section we develop a model which offers an explanation for how communication and knowledge spillovers among the members of a group might affect the individual performance of a team member. As we will see, the expected effect will depend on group size and the degree of within-group diversity. The model is developed for both horizontal and hierarchical teams.

2.3 The theoretical model

The main mechanism of the model is based on the trade-off established between the potential gains from communication across colleagues and the cost that this information exchange has for workers' performance, with group size playing a central role.

As explained in the introduction, this section takes different ingredients from seminal papers studying the organization of knowledge in production, and in particular

the role of diversity and knowledge spillovers in the structure of global firms (see Lazear, 1999b; Garicano, 2000; Antràs et al., 2006a,b), and combines them to build a discrete model, particularly suited to study the effect of group diversity on individual performance in relatively small teams.[28]

We first develop the simplest version of the model, considering only homogeneous and non-hierarchical groups composed by same-type, ex-ante identical workers.

2.3.1 The benchmark model: knowledge spillovers in teams with homogeneous types

A team of size N is composed by $m = N > 0$ type 1 workers. By now we will assume size team is exogenously given, and focus on the worker's problem and the impact of changes in N on his expected individual performance. Each worker's job consists on solving a complex task or problem z. Depending on the state of the world, task z will be of class x with probability p or class y with probability $1-p$. Type 1 workers are only able to solve problems of type x. A type 1 individual i working in isolation such that $m = 1$, will produce $x_i \in [0, X]$ whenever task z is of class x, with x_i given by a draw from the density of production possibilities $f_x(x)$, identically distributed across type 1 workers, and will produce 0 if task z happens to be of class y. The expected production of an isolated type 1 worker i is then simply given by:

$$E[z_1(1,0)] = pE(x_i|m=1) + (1-p)E(y_i|k=0) = pX_1, \tag{2.1}$$

where the arguments of the function z_1 refer respectively to the number of type 1 and type 2 workers in the team,[29] the subscript 1 refers to z being the production of a type 1 worker, and $E(x_i) = E(x) = X_m$ is just the expected value of the highest order statistic from a sample of size m draws from $f_x(x)$.[30] For a type 1 worker in a 1-sized team with $m = 1$, this is simply the mean of the distribution $f_x(x)$.

How should increasing team size to $N = m = 2$ affect the expected performance of worker i? We are talking about an individual's performance in solving a complex task, which she will solve more or less successfully as a function of the information or knowledge available. Hence, while another worker will not directly solve a colleague's task, we can assume that as long as they can communicate with each other, there is a possible gain from colleagues' potentially superior knowledge about the task at hand. In this model, each worker can choose the optimal number of colleagues in her group to communicate with before she knows anyone's realization of $f_x(x)$,[31]

[28] See appendix 2.7.4 for a detailed discussion of the origin of the different elements in the model and the main innovations introduced here, and appendix 2.7.5 for a complete list of the main assumptions on which the model rests.

[29] k gives the number of type 2 workers in the team, always equal to 0 in this section, and so $E(y_i|k=0) = Y_0 = 0$.

[30] For a continuous distribution the expected highest order statistic X_m is a concave function of the sample size. See figure 2.3 in appendix 2.7.6 for an illustration of the expected order statistic for h draws from a $[0,1]$ uniform distribution, and De La Cal and Cárcamo 2005 for relevant results related to the concavity of X_m.

[31] An alternative and equivalent interpretation is that workers commit to communicate before knowing their own and their colleagues' realizations and communication takes place as committed, once these are revealed.

becoming as good in producing x as the best colleague she has talked to. However, in talking with each colleague the worker incurs a communication cost which reduces her total performance given the acquired knowledge by c_s.[32]

Then, being placed in a homogeneous team composed by $m >> 1$ type 1 workers, the —potentially—constrained optimization problem of a worker who wants to communicate with the number of colleagues that maximizes his expected production, consists in choosing the number of team members h to talk to, such that he maximizes expected individual performance $E[z_1(h|m,0)]$, as given by:

$$\begin{aligned} \underset{h}{\text{maximize}} \quad & pX_{h+1} - hc_s \\ \text{subject to} \quad & h \leq m-1, \end{aligned} \tag{2.2}$$

where X_{h+1} is the expected value of the $(h+1)^{th}$ order statistic in a sample of size $h+1$ drawn from $f_x(x)$. The first order condition shows that it is optimal to talk to h colleagues such that this number of workers $\hat{h}$ is the last integer[33] smaller or equal than the critical value h^* for which the partial derivative of the highest order statistic X_{h+1} with respect to h is equal to the cost of communication over the probability p, formally $\partial X_{h+1}/\partial h = c_s/p$. The negative sign of the second order condition guarantees that a unique solution to this constrained optimization problem exists. Figure 2.1 shows the solution to the maximization problem for a type 1 worker in a large enough[34] homogeneous group of size m, populated just by type 1 colleagues.

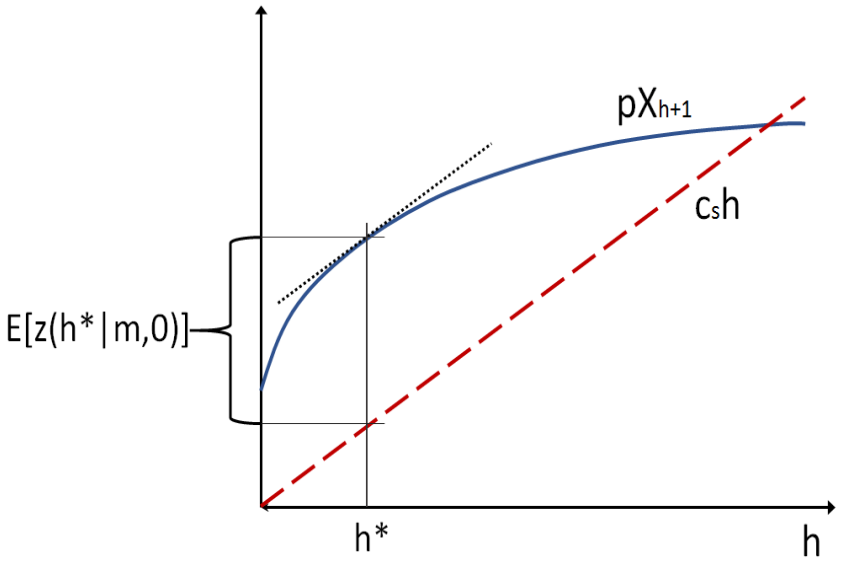


Figure 2.1 – Maximization problem of a type 1 worker in a type 1 homogeneous and large group.

[32]The sub-index s refers to same (type).

[33]The reason for this condition to refer to an integer number of colleagues is that while the expected highest order statistic of any continuous distribution is a continuous function, we assume that agents choose either to communicate or not with each team member, making the set of possible values taken by $\hat{h}$ discrete.

[34]Large enough in the sense that in the set-up reflected in this figure the constraint is not binding, as the optimal number of colleagues for a worker to communicate with, $\hat{h}$ is smaller than the size of the team m.

Basically, communicating to her colleagues allows the worker to improve her expected production, by becoming as good in solving task x as the best worker she has communicated with, minus the costs incurred in communication. This analysis takes us to the two following results:

Proposition 1. *Having an extra colleague in a group has a weakly positive effect on individual performance.*

The fact that workers can freely choose how many colleagues to communicate with implies that the effect on individual performance of introducing an extra worker into a team currently composed of m type 1 workers can only either increase performance if $m-1 \leq h^*$,[35] or not affect it at all if $m-1 > h^*$, as in this case each worker will still talk to the same number $\hat{h} \leq h^*$ of colleagues after the arrival of the newcomer.[36]

Proposition 2. *Whenever the number of colleagues falls in a range in which the effect of having an extra colleague on individual performance is strictly positive, the marginal gain is decreasing on the number of extra colleagues.*

Proof: Take a number $m << \hat{h}$ of colleagues in a given group. The expected gain in individual expected performance for each team member when having a first extra colleague is given by $p(X_{m+1} - X_m) - c_s$, while the gain from having a second extra colleague is given by $p(X_{m+2} - X_{m+1}) - c_s$. Subtracting the second expression from the first one gives $p(X_{m+1} - X_m + X_{m+1} - X_{m+2}) > 0$, by the concavity of X_h ■

In the case of Pakistani tax collectors, these two propositions indicate that we should expect the same worker in a given district to perform better when the number of workers in this district is larger, and this effect to be concave, i.e. performance to increase with the number of colleagues at a decreasing rate.

The timing of the model proceeds as follows. First, workers are hired for performing a task, and they are assembled into a team. Each worker knows the distribution of skills or knowledge across the population, but not their concrete realizations, nor the kind of task to be solved. Second, each worker has to decide with how many colleagues she wants to communicate, committing to do so once the nature of the task and the corresponding individual performances are realized. Third, the task to be solved and each worker's performance in solving it, are revealed to each of the members of the team. After this, communication takes place as committed, and finally each worker performs the task as well as she knows.

In the next section hierarchical teams with different layers are introduced into the model.

Introducing hierarchy with homogeneous teams

The extension of the model to hierarchical teams is directly related to Garicano (2000) from a conceptual point of view, in the way the layers of the hierarchy are characterized by their number of members or dimension and not necessarily by

[35] In a team of size m each worker can at most communicate with $m-1$ colleagues.

[36] In order to keep the model symmetric and simple, by now it is assumed that the number of workers in the team $N = m$ is small enough as for each worker to find it optimal to communicate with all her colleagues.

different levels of authority, and the fact that the agents in each layer have different knowledge or skills, which make them able to solve different tasks.[37]

Hierarchy is introduced into the model in the simplest way possible. Each group or team is now composed by workers distributed in several layers. Each of the layers is defined by its —fixed—number of agents, and by the nature of these workers, who might or not be producers. While the previous literature has typically introduced workers in the bottom and larger layer of a hierarchy (as for example Garicano 2000), here we will consider the possibility of producers being in any layer, not necessarily the larger one. This makes the results from the model more general, making it able to explain cases in which producers are not in the largest layer, as it is the case in our case study.

A team is composed of two layers. Layer 1 is populated by g workers, and layer 2 is populated by l workers. For simplicity, knowledge is not overlapping at all across layers. The solution to the production task faced by each of the producers will be potentially known by the workers in layer 1 with probability q, and by the workers in layer 2 with probability $1-q$. The setting from the previous section applies in each of the layers: if the solution to the task is potentially known by the workers in layer 1, type 1 workers will know the solution with probability p. Importantly, only those l workers in layer 2 are producers, again with density $f_x(x)$. Those workers in layer 1 only contribute to this production process through the information they give to the producers in layer 2. Results are derived without any restriction on the relative size of the layers g and l. By now, the team is homogeneous, as the $g = g_1$ workers in layer 1 and the $l = l_1$ producers in layer 2 are of type 1.[38] The individual cost of communication c_s is defined exactly as before. The problem of a type 1 worker in a homogeneous hierarchical team choosing to communicate with h_a of his g_1 colleagues in layer 1 and h_b of his $l_1 - 1$ colleagues in layer 2 is given by:

$$\begin{aligned} \underset{h_a,h_b}{\text{maximize}} \quad & q\left(pX_{h_a}\right) - h_a c_s + (1-q)\left(pX_{h_b}\right) - (h_b - 1)c_s \\ \text{subject to} \quad & h_a \leq g_1, \\ & h_b \leq l_1 - 1. \end{aligned} \tag{2.3}$$

The two first order conditions are given by:

$$qp\frac{\partial X_{h_a}}{\partial h_a} - c_s = 0$$

and

$$(1-q)p\frac{\partial X_{h_b}}{\partial h_b} - c_s = 0.$$

As one would expect, these conditions show that the number of type 1 workers in each layer that each producer will optimal choose to communicate with is increasing on the probability of these workers knowing the solution to the task, respectively qp

[37] The similarity is mainly conceptual because the discrete nature of this model, as opposed to Garicano's, and the cost of communication being symmetric here instead of falling on the receiver, plus the —later—introduction of two different types of agents make the two models very different.

[38] The subscript in g_1 and l_1 indicates the type of the workers.

and $(1-q)p$. The concavity of X_m with respect to sample size m gives the negative sign of both second order conditions, which guarantee that the problem has a unique solution, for each of the two variables. Hence, the expected production of a type 1 producer i in such a hierarchical team is given by

$$E[z_1(h_a, 0; h_b, 0)] = q\left(pX_{h_a}\right) - h_a c_s + (1-q)\left(pX_{h_b}\right) - (h_b - 1)c_s.$$

which can be simply written as

$$E[z_1(g_1, 0; l_1, 0)] = q\left(pX_{g_1}\right) - g_1 c_s + (1-q)\left(pX_{l_1}\right) - (l_1 - 1)c_s,$$

under the assumption that g_1 and l_1 are small enough as for every worker to find it optimal to communicate with all their colleagues, in both layers.[39]

Whether hierarchy matters in a really meaningful way requires a positive answer to the following question: does the placement of colleagues in one or another layer make any qualitative difference for their impact on the individual expected performance of producers?

The answer to this question is a qualified yes, as it just requires a small twist to the model: that the structure of the group is such that each non-producer does not find it optimal to communicate with all of the producers. One could expect this to be the case in many real world settings. The mechanism through which hierarchy matters in this context is easier to understand if we think of knowledge in terms of demand and supply, as a scarce resource in an environment in which the number of non-producers is less than it would be optimal for producers' individual performance. In this context, a given producer will not find as many colleagues willing to communicate with him as he would like to. The next two results show in which sense hierarchy matters when this is the case:

Proposition 3. *Having an extra colleague in a different layer always has a weakly positive impact on the expected performance of individual producers.*

Having an extra colleague in another layer can be interpreted as an increase in the supply of knowledge or skills available to the producers in the team. The reasoning is exactly the same as for the effect of having an extra colleague in teams without hierarchy: if the number of colleagues is too large the producer can just choose to not communicate with part of them, so the effect should never be negative.

This result holds also in the context in which each of the g_1 workers in layer 1 do not find it optimal to communicate with all the l_1 producers in layer 2, even if each of producer would like to communicate with all of his g_1 colleagues. Take for example the case in which each worker in layer 1 and each worker in layer 2 finds it optimal to communicate with the same number λ of colleagues in the other layer,[40] but the number of workers in each layer is unequal, such that $g_1 < l_1$. In

[39] This amounts to the existence of an implicit optimization problem for those non-producer workers in layer 1, who optimally choose to communicate with every producer in layer 2.

[40] These same argument could be developed for layers with the same size but a different number of optimal connections for the workers in each layer. In general, both a divergence in layers' size or in the optimal number of connections for workers in different layers can imply that not every non-producer wants to communicate with every producer.

this context, each producer will get to communicate in average with $\lambda g_1/l_1 < \lambda$. An extra colleague in layer 1 will increase the average number of communications per producer to $\lambda(g_1+1)/l_1$, increasing individual expected performance.[41] This is not necessarily the case for the effect of having an extra colleague in the same layer.

Proposition 4. *Having an extra colleague in the producers' layer might have a negative effect on individual performance.*

Again in the same context in which the workers in layer 1 do not find it optimal to communicate with every worker in layer 2, having an extra colleague in the producers' layer can be interpreted as an increase in the demand for layer 1 knowledge, increasing competition for this scarce resource. From an initial situation with g_1 and l_1 workers per layer, in which each producer in layer 2 is communicating in average with $\lambda g_1/l_1$ layer 1 colleagues, an extra layer 2 producer decreases the average number of communications with layer 1 colleagues to $\lambda g_1/(l_1+1)$. Whenever the loss in communication derived from this change is higher than the gain derived from communicating with the new same-layer colleague, the net impact of this extra colleague on individual performance will be negative.[42]

In the context of Pakistani tax collectors these results indicate that we should expect a higher number of colleagues in the layer of 'other workers' to be associated with a higher performance, while having a larger number of AC colleagues could potentially be associated with a lower individual performance.

In the next section, type 2 workers are introduced into the model. Given that we will stick to the assumption of m, g_1 and l_1 being small enough as for every producer to optimally choose to talk to all of her colleagues, we skip to present the maximization problem of the producers in each of the different subsections. Their similarity with the maximization problems in the case of homogeneous teams makes them somehow redundant and not particularly illustrative: with knowledge being exclusive across types, including workers of a different type does not affect at all the optimal number of his own-type colleagues a given worker optimally chooses to communicate with.

2.3.2 Introducing diverse workers: knowledge spillovers and heterogeneous types

A team of size N is now potentially composed of $m > 0$ type 1 workers and $k \geq 0$ type 2 workers. As in the previous section, we assume that N, m and k are exogenously given, and focus on their impact on workers' individual expected performance.

Similar to type 1 workers, a type 2 worker is characterized by a density of production possibilities $f_y(y)$. The production process faced by these workers is the same as in the previous section, with type 1 workers being able to solve the complex process with probability p, and type 2 workers with probability $1-p$. Similarly to type

[41] It is straightforward to check that the effect of having an extra colleague in layer 1 on the expected performance of individual producers should be concave on the number of layer 1 workers, as long as the marginal effect is strictly positive.

[42] The combination of these two opposed effects makes it difficult to predict the nonlinear shape of the net effect.

1 workers, when the state of the world is such that workers of type 2 can solve the problem at hand, agent j's production in isolation is given by a draw from the corresponding density, y_j. Trivially, in isolation the expected production for each type of worker is respectively given by pX_1 and $(1-p)Y_1$, the expected highest order statistic drawn from the corresponding density in a sample of size 1, multiplied by the probability that the problem can be solved by that kind of worker.

Any type of worker can potentially improve over its expected performance in isolation by communicating both within and between types. To communicate with a worker of a different type costs c_o, which can be interpreted as the difference between the between-type and within-type cost of communication, and so for simplicity in this section the cost of between-type communication c_s is normalized to 0.[43] With $z_1(m,k)$ defined as the expected production of a type 1 agent, and $z_2(m,k)$ as the expected production of a type 2 agent, in a group with m type 1 workers and k type 2 workers in which every worker communicates with each other,[44] the expected performance for a type 1 worker is given by

$$E[z_1(m,k)] = pX_m + (1-p)Y_k - kc_o, \tag{2.4}$$

and similarly, the expected production for a type 2 worker $j = 1, ..., k$ is

$$E[z_2(m,k)] = pX_m + (1-p)Y_k - mc_o. \tag{2.5}$$

Whether it is optimal or not for aggregate performance to combine both types of workers in a single team is analyzed in section 2.5. Here we study the effect of different combinations of workers on expected individual performance.

Combining heterogeneous workers and individual expected performance

How does the combination of workers of different types affect the expected performance of individual workers? In order to answer this question, we now proceed to analyze the marginal effect of substituting a worker of a given type by a worker of a different one, characterizing how this effect depends on the existing team composition, as given by the initial number of type 1 workers and type 2 workers in the group.[45] N is kept fixed.

For simplicity, the analysis is reduced to the case of the substitution of a type 1 worker by a type 2, in a team initially composed by respectively m and k workers of each type. For a type 1 colleague who is part of the team both before and after the substitution, the change in expected performance is given by

[43] Here we are interested in the difference between within and between-group cost of communication. Hence, normalizing the within type cost of communication to 0 simplifies the model without reducing its capacity to explain the main mechanism. Also, this is a standard assumption in the literature, see Lazear 1999.

[44] As said, now we assume the number of team members of each type m and k is small enough as for workers to optimally choose to communicate with all of their colleagues.

[45] Note this is exactly the same as comparing the expected performance of workers in two different groups with N workers each, one of the groups having respectively m and k type 1 and type 2 workers, and the other having $m-1$ and $k+1$.

$$E[z_1(m-1,k+1)] - E[z_1(m,k)] = p(X_{m-1} - X_m) + (1-p)(Y_{k+1} - Y_k) - c_o. \quad (2.6)$$

This condition reads that the expected performance of a worker of a given type increases with the substitution of a same-type worker by a worker of a different type if and only if the expected gain in information is larger than the expected loss of information plus the between-type communication cost.

As in general $c_o > 0$, this might only be the case when $(1-p)(Y_{k+1} - Y_k) > p(X_m - X_{m-1})$: the expected gain in information net of costs of communication derived from the incorporation of the type 2 worker must be larger than the loss derived from the departure of the type 1. Notice that condition (2.6) is decreasing on k and increasing on m. This has an important implication:

Proposition 5. *If one type 1 worker is substituted by one type 2 worker in two different teams with the same number of type 2 workers, but otherwise different sizes, the gain in expected individual performance for each of the remaining type 1 workers will be larger for those in the larger group.*

See appendix 2.7.7 for the proof. In terms of the Pakistani tax collectors, this should imply that if two teams have only one military each, the contribution of this military colleague to the performance of the civilian colleagues should be larger in the larger team than in the smaller one.

How does the effect of a substitution of a type 1 colleague for a type 2 one compare for type 1 and type 2 workers? With the effect of substituting a type 1 colleague by a type 2 on type 1 workers' performance given by equation (2.6), and the effect of this same substitution on a type 2 worker given by

$$E[z_2(m-1,k+1)] - E[z_2(m,k)] = p(X_{m-1} - X_m) + (1-p)(Y_{k+1} - Y_k) + c_o, \quad (2.7)$$

the difference between these effects is simply given by subtracting equation (2.6) from (2.7), as:

$$\{E[z_2(m-1,k+1)] - E[z_2(m,k)]\} - \{E[z_1(m-1,k+1)] - E[z_1(m,k)]\} = 2c_o.$$

Hence, while the effect of information net of communication costs is exactly the same for both types of workers, there is an important difference: with each substitution of a type 1 colleague by a type 2 colleague, the type 2 workers 'save' an extra c_o, instead of 'paying' it, as a type 1 does. This implies that the substitution of a type 1 colleague by a type 2 one will increase the expected performance of a type 2 worker by $2c_o$ more than that of a type 1 worker. This result is formally expressed by proposition 6.

Proposition 6. *Substituting workers of a different type in a given group always increases more the expected performance of those workers with the same type as the newcomer, than the performance of those workers with the same type as the worker leaving the team. The difference between the contribution of this substitution to the expected individual performance of each type of worker is directly proportional to the difference between the between-type and within-type costs of communication.*

In terms of Pakistani tax collectors, this should imply that having an extra military colleague in a given group should increase more the performance of the military colleagues in the team than that of the civilian ones.

Knowledge spillovers, heterogeneous types, and hierarchy

Now, again a team is composed of two layers. Layer 1 is populated by g workers, and layer 2 is populated by l producers, with g_1 type 1 workers and g_2 type 2 workers in layer 1, and l_1 type 1 workers and l_2 type 2 producers in layer 2. The setting from the previous section applies to each of the layers. Again, the number of workers of each type in each layer is assumed small enough with respect to c_o as for each worker to find it optimal to communicate with each of her colleagues. Finally, The expected production of a type 1 producer i in the layer 2 of this hierarchy is given by

$$E[z_1(g_1, g_2; l_1, l_2)] = q\left(pX_{g_1} + (1-p)Y_{g_2}\right) - g_2 c_o \\ + (1-q)\left(pX_{l_1} + (1-p)Y_{l_2}\right) - l_2 c_o, \quad (2.8)$$

and similarly, for a type 2 producer the expected performance is

$$E[z_2(g_1, g_2; l_1, l_2)] = q\left(pX_{g_1} + (1-p)Y_{g_2}\right) - g_1 c_o \\ + (1-q)\left(pX_{l_1} + (1-p)Y_{l_2}\right) - l_1 c_o. \quad (2.9)$$

The analysis in this section focuses on the relationship between different combinations of workers in hierarchical groups and the expected performance of individual producers (each of the workers in layer 2). As with N for the case of non-hierarchical groups, g and l are kept fixed, and we focus on the marginal effect of substituting a type 1 worker by a type 2, characterizing how this effect depends on the existing team composition and on which layer of the hierarchy the substitution takes place.

The effect of substituting one of the original g_1 non-producer, type 1 workers by a new type 2 worker in layer 1, is given by the comparison $E[z_1(g_1 - 1, g_2 + 1; l_1, l_2)]$-$E[z_1(g_1, g_2; l_1, l_2)]$ as:

$$q[p(X_{g_1-1} - X_{g_1}) + (1-p)(Y_{g_2+1} - Y_{g_2})] - c_o. \quad (2.10)$$

The only difference between this condition and the result in (2.6) for the case without hierarchy, is that the change in expected performance net of communication costs, given by the first term of the expression is here multiplied by q. The interpretation is

straightforward. The higher the probability of the solution to the task being known by workers in layer 1 q, the more that the substitution matters, both in the case that this implies a gain in expected information and if it implies a loss. If q tends to 0 the change only reduces the expected performance of a type 1 producer by the increase in communication cost c_o,[46] and if q tends to 1 this condition in exactly the same as that for the case without hierarchy.

For a substitution in layer 2, the effect on the performance of type 1 producers of substituting another type 1 producer by a type 2 one, given by $E[z_1(g_1, g_2; l_1-1, l_2+1)]$-$E[z_1(g_1, g_2; l_1, l_2)]$ differs from the effect of an equivalent substitution happening in layer 1 —see equation 2.10—, just in that q is replaced by $1-q$ and g by l, giving

$$(1-q)[p(X_{l_1-1} - X_{l_1}) + (1-p)(Y_{l_2+1} - Y_{l_2})] - c_o. \tag{2.11}$$

Equations (2.10) and (2.11) give us a within-layer result which does not need to be explained, given its high similarity with proposition 5. Testing it empirically will increase the robustness of the suggested mechanism:

Proposition 7. *If one type 1 worker is substituted by one type 2 worker in the same layer of two groups which are equal in everything except for the total number of type 1 workers in that layer, the effect of this substitution on the performance of the type 1 producers should be more positive for those in the group with the larger layer.*

Another related result is the comparison between the effect of such a substitution depending on the layer in which it takes place, formally given by $\{E[z_1(g_1-1, g_2+1; l_1, l_2)]$-$E[z_1(g_1, g_2; l_1, l_2)]\}$-$\{E[z_1(g_1, g_2; l_1-1, l_2+1)]$-$E[z_1(g_1, g_2; l_1, l_2)]\}$. Subtracting equation (2.11) from equation (2.10) results in:

$$q\{p[X_{g_1-1} - X_{g_1}] + (1-p)[Y_{g_2+1} - Y_{g_2}]\} - (1-q)\{p[X_{l_1-1} - X_{l_1}] + (1-p)[Y_{l_2+1} - Y_{l_2}]\}. \tag{2.12}$$

Basically, the optimality for individual producers'[47] performance of making the substitution of one type 1 by a type 2 in layer 1 instead of layer 2 is increasing on g_1 and l_2 and decreasing on g_2 and l_1. To see this clearly, if we assume the number of initial type 2 workers in each layer g_2 and l_2 to be fixed, we get a result equivalent to proposition 5 for the problem without hierarchy: everything else equal, for a fixed number of type 2 workers in a given layer, the gain in the expected performance of individual producers from the substitution of a type 1 colleague by a type 2 increases with the size of the layer, N or equivalently with the number of type 1 producers in the layer, m.

In a context in which $q \approx 1-q$, this implies that the effect of this substitution will be more positive if happening in the larger layer. In general, if the two terms on equation (2.12) have the same sign, the optimality of making the substitution in one

[46] Of course, in the extreme a producer in layer 2 would never optimally choose to communicate with a colleague in layer 1.

[47] Of any type, as c_o disappears from the condition.

or another layer will depend on q. however, there is a general result which holds whenever one of the two terms is positive and the other is negative, or zero:

Proposition 8. *For the two layers of a team with different size but the same number of type 2 workers each, if substituting a type 1 worker by a type 2 has a weakly positive effect —on the performance of the remaining type 1 producers—in one layer and a negative effect in the other one (or* vice versa*), the negative effect must correspond to the substitution in the smaller layer.*

To see how this result holds in general one only needs to notice that for $Y_{l2} = Y_{g2}$, the first term in equation (2.12) can only be negative and the second one positive (or *vice versa*) if $X_{g1} < X_{l1}$ ($X_{g1} > X_{l1}$), independently of q.[48]

For a team with three layers with the same number of type 2 workers in each of them, this would imply that if the effect of substituting a type 1 worker by a type 2 on the performance of the remaining type 1 producers is positive in layer A, it is zero when the substitution takes place in layer B, and it is negative when taking place in layer C, we must have that $N(A) > N(B) > N(C)$, where $N(\cdot)$ refers to the number of workers in the corresponding layer.

In the context of Pakistani tax collectors this should imply that if the average effect of having military colleagues on type 1 performance diverges in sign across layers, it should be more negative in the smaller layer (supervisor) and more positive in the larger one (other workers).

2.4 Empirics

The empirical study is developed using a novel panel data set in monthly frequency, built from confidential documents belonging to the Pakistan Administrative Services. In this section we first describe the data used for the study of the individual performance of Pakistani tax collectors. After carefully describing the data on targets for tax collection and actual recovery, and the information available on Assistant Commissioners (ACs) and the characteristics of their group-members: those civil servants working at the same district in the same period, we proceed to test the main predictions from the theoretical model empirically.

2.4.1 Tax collection, targets, and our measure of performance

The original documents

The personal and professional information about each civil servant has been extracted from the 'Individual Career Planning Chart', the file used by the PAS to keep track of their employees. The first part of this document contains a picture of the worker, its id. number, name and date of birth, and a complete list of the

[48] Proposition 8 directly applies also to the comparison between a positive or a negative effect and a zero effect

postings and stations the worker has been allocated to along its career in the civil services, together with her supervisors' evaluation of her performance in the post and her fitness for promotion, see figure 2.4 in appendix 2.7.8. The second part contains personal information, such as the domicile, the district of origin and date of birth, the religion, the academic and professional titles, training received, languages spoken, marital status, the occupational group service, or the date of promotion to each of the different grades, see figure 2.5.

In order to complete the data-set, the data extracted from this document has been matched with the measure of performance, only available for ACs. This measure, given by the amount of agricultural tax collected in a tehsil in the corresponding month divided by the annual tax target, as described below, was extracted for each case from one of two documents. The first of them is the 'Statement showing the recovery position of agricultural income' for a given tehsil and month, see figure 2.6 in appendix 2.7.9. It contains the target tax —based on the official record of size and number of farmlands —for the financial year and the recovery during the month, among other measures related to the target tax and the amount of taxes collected. This form is completed by the corresponding AC in charge of that tehsil at that given period, and signed by her supervisor (DC). The second document consists of a listing of the tax collected in the corresponding month in each of the tehsils in a given district, see figure 2.7 in appendix 2.7.9. This document is completed by the Deputy Commissioner (DC) using the statement handed to her by each of the ACs she supervises. As can be seen there are two kinds of targets: one is for the current financial year and the other is for arrears from all the past financial years. For the purpose of this study we restrict attention to the performance against targets set for the current financial year.[49] Tax collected each month is under the title 'current recovery' or under 'recovery during the month'.

Our measure of performance.

The performance measure is compiled from historical records of the provincial Board of Revenue (BOR) on Land Revenue/Agriculture Income Tax (AIT) from 1983-2013. The Punjab Agricultural Income Tax (AIT) Act 1997 replaced the Punjab Land Revenue Act, 1967. Land Revenue contemplated a tax on area cultivated, while AIT was meant to impose a tax on the agricultural income of an owner in a tax year.

Assistant Commissioners are supposed to report back the tax collected each month against these annual targets. This gives us the monthly performance measure for the ACs:

$$Tax\ performance = \frac{Tax\ collected\ in\ the\ month}{Annual\ tax\ target}$$

[49] Since the current financial year is the main priority of the government, ACs expend more effort trying to meet these targets. Annual targets are provided in the column titled 'demand'.

Targets for tax collection

The high difficulty in the administrative tracking and documentation of agricultural income in the rural economy of Pakistan, together with the fact that the revenue administration is obliged by law to keep a detailed record of land owned, imply that for all practical purposes agricultural taxes have remained a tax on area sown (Nasim, 2012). The only of the two rules for tax collection contemplated by the AIT[50] which is enforceable in practice is the one for which the revenue authorities keep a detailed record i.e. farmland owned. Hence, in practice the BOR sets annual tax collection targets based on the official record of size and number of farmlands.[51]

The definition of an observation and ACs' performance in our data

An observation in our study corresponds to the performance of a given AC in a given month. There are a total of 7,108 observations in our data-set. The average monthly performance across all workers is 7.73% of the annual target, with an standard deviation equal to 13.68%, the minimum value is 0% and the maximum 100%. 6,938 of these observations correspond to non-military ACs, with a mean performance of 7.69% and a standard deviation of 13.65%.

As one would somehow expect, average performance is typically higher for those months closer to the end of the financial year (December to June), and lower for the first five months in the financial year (July to November), see figure 2.10 in appendix 2.7.11.

This AC is placed in a certain tehsil in that period, and so we know with which other civil servants she is working at the time. Here 'working with' is defined as being placed in the same district at the same time. For the purpose of this study, all workers satisfying this condition will be considered members of the same group, in that given period.

We have data on a total of 1372 civil servants between February of 1987 and December 2013. Among these workers, 649 of them work at some point during these time interval as Assistant Commissioners (ACs) at a tehsil and month for which information on performance is available —see the column 'with info on performance'. Other 723 colleagues work at some point of their careers in different positions (not as ACs), in districts and months in which at least one AC has information on performance —see the column 'In districts with info on performance'. Table 2.2 shows the distribution of workers across different types, and the corresponding number of observations.[52]

[50] See appendix 2.7.3 for an official description of the two rules contemplated for setting the agricultural tax corresponding to a given producer, as regulated by the AIT.

[51] A potentially interesting direction for future research is to study in detail the relationship between targets and performance. A first visual exploration of the data shows that the average annual (by financial year) tax target across tehsils in our data has a large variability, see figure 2.8 in appendix 2.7.10. Interestingly, an equivalent graphic for monthly average performance per financial year points towards a possible negative correlation between these two variables, see figure 2.9.

[52] The division of civilian workers in PAS and PMS is included in the table to make it possible to appreciate how close the number of military workers (and observations) is to the quota of a 10%

		With info on performance		In dist. with info on perf.	
		Workers	Observations	Workers	Observations
Civilian	PMS	401	5105	817	22526
	PAS	211	1735	421	5626
Military	PAS	25	170	70	920
Total		649	7108	1372	30035

Table 2.2 – Number of ACs with information on performance and the corresponding number of observations, and the same for those civil servants working in the same district as some of these ACs at the same time.

2.4.2 The distribution of workers in groups and layers

With a group defined as the set of civil servants working in the same district in a given period for which at least one AC has information on performance, there are 3,083 groups in our data-set.

As explained in section 2.2.1 we will considered groups as hierarchical, and divided in three different layers, respectively composed by the DC, the ACs, and the 'other workers'. Table 2.3 shows the distribution of workers in each of the three layers for all the workers and just for the military. In each case, the column 'Total' gives the number of times a worker is present in the corresponding layer in one of the groups, while the column 'Average group' gives the average number of workers in the corresponding layer, across all groups. We can see how layer 1, corresponding the DC is typically the smallest one, layer 3 containing 'other workers' is generally the largest, and the ACs' layer is in-between these two, with an intermediate average size.

	All workers		Military	
	Total	Average group	Total	Average group
DCs	1527	0.495	193	0.063
ACs	7996	2,593	190	0.061
Others	20512	6.653	537	0.174

Table 2.3 – Distribution of workers across the different layers of the 3,083 groups in which at least an AC has information on performance.

2.4.3 The main variables

From the information available in the official documents, a series of variables are created. These will allow us to study the relationship between diversity, group size and performance, and the role played by the hierarchical structure of groups. The main variables used in the study are the following:[53]

- Y: the performance of tax collector (AC) in the corresponding period, given by *tax collected/annual tax target*.

of the PAS.

[53] See table 2.7 in appendix 2.7.12 for descriptive statistics.

- *colleagues*: the number of workers in a given district and period.
- *colleagues_exp*: the variable *colleagues* exponentiated, in order to capture the hypothesized non-linear effect of the number of colleagues. After exploring different exponents, we choose to use the variable $colleagues\_exp = colleagues^{3.5}$, as raising the variable to the power 3.5 seems to maximize the significance of the two coefficients associated to *colleagues* and *colleagues_exp*.[54]
- *AC_colleagues*: the number of *AC* colleagues the tax collector (also an AC) works with in the same district in the corresponding period.[55] The variable *AC_coll_exp* is built through the same exponential transformation of *AC_colleagues* as that which creates *colleagues_exp* as a function of *colleagues*: $(AC\_coll\_\ exp = AC\_colleagues^{3.5})$.
- *other_colleagues*: the number of civil servants working in other departments of the same district in the corresponding period, who are not *DCs* or *ACs*.[56] These compose the typically larger layer 3, the 'other colleagues' layer. The variable *other_coll_exp* is built through the same non-linear transformation as *colleagues_exp* and *AC_coll_exp*: $(other\_coll\_exp = other\_colleagues^{3.5})$.
- *military*: a dummy variable which takes value 1 if the corresponding AC is originally from the army, and 0 otherwise. This variable is not included in most of the regressions, as generally these explain just the performance of non-military tax collectors.
- *mil_coll*: a dummy variable which takes value 1 if there is at least one military worker in the current district and period.
- *N_mil_coll*: the number of military colleagues in the current district and period.[57]
- *DC_mil_coll*: a dummy variable which takes value 1 if the Deputy Commissioner in the district comes from the army and 0 otherwise.
- *AC_mil_coll*: a dummy variable which takes value 1 if there is a military AC in the current district and period, and 0 otherwise. The number of cases in which two military ACs work together in the same district is negligible.
- *other_mil_coll*: the number of military 'other workers' in the current district and period.[58]
- Controls: these include worker time-varying characteristics, such as a dummy variable which takes value 1 if the worker is in its first ever post and 0 otherwise,

[54] Other exponential transformations of *colleagues*, such as taking its squared value, offered qualitatively equivalent results which were also statistically significant.

[55] See figure 2.11 in appendix 2.7.13 for the distribution of the number of *AC_colleagues*, for the tax-collectors in our data.

[56] See table 2.13 in appendix 2.7.15 for the distribution of the number of *other_colleagues*, for the tax-collectors in our data.

[57] Most of the ACs with some military colleagues in their current team have only one. See appendix 2.7.14 for descriptive statistics about the distribution of the number of military colleagues for the ACs in our sample.

[58] 92% of the ACs with some 'other military worker' in their same district has only 1 colleague of such type.

the age of the worker in months, or the number of months the worker has served as a civil servant.

- Fixed Effects: in most regressions we will include Fixed Effects for the individual worker, the current district, financial year (July of one year to June of the next one) and month (January to December).

In the next section we use these variables to test the predictions from the theoretical model in the context o the Pakistan civil services.

2.4.4 Testing the theory

The analysis is developed using pooled Ordinary Least Square (OLS) regressions, so these empirical results do not attempt to be a causal explanation of the suggested mechanism, but to serve as descriptive evidence.

This section follows the same structure as the theoretical part of the paper, studying first the case of homogeneous teams and considering heterogeneous teams afterwards.

Homogeneous groups

This first part of the empirical analysis is developed focusing on the number of colleagues, in the full group and in each of the layers. The theoretical model predicts a higher number of colleagues to be associated with a higher performance at a decreasing rate. This should also be the case for the number of workers in non-producer layers (in this case non-ACs), while the number of ACs in the group could take any sign.

The analysis is developed without considering diversity across different workers, and so considering both civilian and military civil servants as equal. This approach has the advantage of being based on the whole sample. An alternative way to proceed would be to limit the sample of study, such that this includes only those groups without any military worker in any position. Using this selected sample would have the advantage of containing only homogeneous groups along the criterion used to define diversity. Given the relatively small proportion of military workers, both approaches produce equivalent results.

Considering the whole set of workers in the district as the flat or non-hierarchical group, we study the effect of group size on the performance of civilian tax collectors, excluding the performance of military tax collectors from the analysis. Proposition (1) implies that we should expect the performance of a given worker in a given group or district to be higher when the number of workers in this district is higher. We start from a linear equation that estimates the performance Y_{ikdmt} of tax collector i in tehsil k and district d, in month m and financial year t, as:

$$Y_{ikdmt} = \alpha_{i1} + \beta_1 colleagues_{dmt} + \delta_1 X_{ikdmt} + \varphi_{d1} + \lambda_{m1} + \phi_{t1} + \epsilon_{ikdmt} \qquad (2.13)$$

where α_{i1} is the fixed effect for individual i, our main variable of interest $colleagues_{dmt}$ is the number of workers in district d, month m and financial year t, X_{ikdmt} are tax

collector i's time-varying observable characteristics,[59] and φ_{d1}, λ_{m1} and ϕ_{t1} are respectively district, month and financial year fixed effects. Finally, ϵ_{ikdmt} is the error term, clustered at the tehsil level.[60]

For proposition 1 in the theoretical model to hold the coefficient β_1 should be positive. As the results in column (1) of table 2.4 show this coefficient, corresponding to *colleagues* is in fact positive, but small and it is not statistically significant.[61]

This first regression is missing the incorporation of a non-linear measure of the number of colleagues, a potentially important element for the right assessment of the association between the number of team members and individual performance, in non-hierarchical, homogeneous groups. We incorporate this non-linear element to regression (2.14) by including *colleagues_exp* as an extra variable, with the full regression given by:

$$Y_{ikdmt} = \alpha_{i2} + \beta_{2a} colleagues_{idmt} + \beta_{2b} colleagues\_exp + \delta_2 X_{ikdmt} + \varphi_{d2} + \lambda_{m2} + \phi_{t2} + \epsilon_{ikdmt} \quad (2.14)$$

Proposition (1) in the theoretical model would be supported by the data if $\beta_{2a} > 0$, and proposition (2) if $\beta_{2b} < 0$. The results for regression (2.14), in column (2), table 2.4 show that both conditions are satisfied: β_{2a} is positive and β_{2b} is negative, and both are significant at the 1%. While β_{2b} might seem very small, these two coefficients imply a coherent interpretation of the marginal effect of an extra colleague on the performance of civilian tax collectors.[62]

In summary, as predicted by the theoretical model, having an extra colleague is associated with a higher individual performance for civilian tax collectors in Punjab, but this marginal gain decreases with the number of colleagues in the group.

Still considering just homogeneous groups and the performance of civilian tax collectors, we proceed to study the association between group size and individual performance taking hierarchy into account. The top layer, for the supervisor or Deputy Commissioner has either one or zero workers, thus not allowing for the analysis of the relationship between layer size and individual performance (a regression including a dummy variable for having a DC in the district in that month has a positive but not statistically significant coefficient).

The regressions which study the effect of the size of the ACs layer on the performance of individual ACs in the group are basically the same as regressions (2.13) and

[59] In sake of a clearer presentation, each column in the regression tables reports only the main variables of interest. In order to not create an omitted-variable bias problem, relevant variables which are not the main variable of interest in each regression, such as the number of colleagues of different types, and the associated non-linear terms are included as controls.

[60] For the remaining of the paper the error term will be clustered at the tehsil level in every regression.

[61] While not significant the number of colleagues in this first regression is very close to statistical significance, with a p-value of 0.103.

[62] See appendix 2.7.16 for an illustration of the interpretation of this marginal effect of an extra colleague, conditional on group size.

(2.14), with the only difference being the substitution of the variable *colleagues* by *AC_colleagues* and *colleagues_exp* by *AC_coll_exp*, resulting in:

$$Y_{ikdmt} = \alpha_{i3} + \beta_3 AC\_colleagues_{idmt} + \delta_3 X_{ikdmt} + \varphi_{d3} + \lambda_{m3} + \phi_{t3} + \epsilon_{ikdmt} \quad (2.15)$$

and

$$Y_{ikdmt} = \alpha_{i4} + \beta_{4a} AC\_colleagues_{idmt} + \beta_{4b} AC\_coll\_exp + \delta_2 X_{ikdmt} + \varphi_{d4} + \lambda_{m4} + \phi_{t4} + \epsilon_{ikdmt} \quad (2.16)$$

The corresponding results are shown in columns (3) and (4) in table 2.4. The coefficient on *AC_colleagues* β_3 is negative and significant, pointing towards a negative association between the number of ACs in the same group and individual performance. With the introduction of the non-linear term *AC_coll_exp*, the coefficient associated to *colleagues* in this regression β_{4a} is not statistically significant, while the coefficient associated to the non-linear term β_{4b} is negative and significant, indicating a marginal effect which becomes more negative as the number of AC colleagues increases.[63]

The regressions studying the effects of the size of the 'other workers' layer on the performance of individual ACs, are also basically the same as regressions (2.13) and (2.14), except for the substitution of *colleagues* by *other_colleagues* and *colleagues_exp* by *other_coll_exp*:

$$Y_{ikdmt} = \alpha_{i5} + \beta_5 AC\_colleagues_{idmt} + \delta_5 X_{ikdmt} + \varphi_{d5} + \lambda_{m5} + \phi_{t5} + \epsilon_{ikdmt} \quad (2.17)$$

and

$$Y_{ikdmt} = \alpha_{i6} + \beta_{6a} AC\_colleagues_{idmt} + \beta_{6b} AC\_coll\_exp + \delta_6 X_{ikdmt} + \varphi_{d6} + \lambda_{m6} + \phi_{t6} + \epsilon_{ikdmt} \quad (2.18)$$

The results for these two equations are respectively shown in columns (5) and (6) of table 2.4. As one can see there, the coefficient β_5 is positive and significant, indicating that having an extra 'other colleague' in the district is associated with a higher individual performance for tax collectors. With the inclusion of *other_coll_exp*, the coefficient associated to the linear term β_{6a} increases in size, while the coefficient associated to the non-linear term β_{6b} is negative, indicating a positive but decreasing relationship between the number of civil servants in the 'other workers' layer and the individual performance of the tax collectors in the corresponding district.

As we can see, the layer of the hierarchy at which the extra colleague is working makes an important difference to the association between having this extra colleague and the performance of civilian tax collectors. While having an extra colleague in the larger layer of 'non-producers' or 'other workers' is associated with a higher

[63] Visual exploration of average performance as a function of the number of AC colleagues in the same district broadly illustrates this relationship, see figure 2.14 in appendix 2.7.17.

performance at a decreasing rate, as predicted by proposition 3, having an extra Assistant Commissioner is associated with a lower individual performance for civilian tax collectors, a possibility contemplated by proposition 4.

The interpretation of the coefficients for *AC_colleagues* and *AC_coll_exp* in light of the model is the following: an increase in the number of ACs in the group should have two opposed effects. On the one hand, and extra AC in the group brings potentially new and useful information, with a potentially positive effect on her AC colleagues' performance. On the other hand, an extra AC might imply increasing competition for communication with the rest of colleagues in the team, as now there is an extra producer who wants to talk to others. The negative sign of β_5 and β_{6b} points towards the negative effect of 'competition for communication' dominating the positive effect. The negative sign of β_{6b} also indicates that the negative effect seems to grow faster with the number of AC colleagues in the group than the positive one.

It is straightforward to check that the inclusion of non-linear terms still produce sensible estimates for the relationship between the number of colleagues and individual performance.

	(1) perf	(2) perf	(3) perf	(4) perf	(5) perf	(6) perf
colleagues	0.024	0.180***				
	(0.014)	(0.060)				
colleagues_exp		-8.91e^{-7}***				
		(2.95e^{-7})				
AC_colleagues			-0.585**	-0.280		
			(0.288)	(0.310)		
AC_coll_exp				-0.003**		
				(0.001)		
other_colleagues					0.025*	0.183***
					(0.014)	(0.060)
other_coll_exp						-11.3e^{-7}***
						(3.70e^{-7})
Controls	Yes	Yes	Yes	Yes	Yes	Yes
District FEs	Yes	Yes	Yes	Yes	Yes	Yes
Financial_yr FEs	Yes	Yes	Yes	Yes	Yes	Yes
Month FEs	Yes	Yes	Yes	Yes	Yes	Yes
Individual FEs	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6935	6935	6936	6935	6935	6935

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.4 – Pooled OLS, results for the case of homogeneous groups, without considering diversity.

While the size of the marginal effect of each extra colleague might seem small, in reality their relationship with individual performance is very important in quantitative terms. As we can easily estimate from table 2.8 in appendix 2.7.16, everything else equal a civilian tax collector with 25 colleagues is expected to have an average performance which is higher than the expected performance of an equivalent worker with 5 colleagues by approximately a 3.4% of the annual target. This is close to half of the average monthly performance for civilian ACs, and about one fourth of its standard distribution.

A similar analysis shows that the magnitude of the coefficients associated to the variables related to the number of AC colleagues and 'other' colleagues are also quantitatively relevant.

Heterogeneous groups without considering hierarchy

In this section we proceed to test empirically the predictions derived from the theoretical model about the relation between the individual performance of civilian tax collectors and having military colleagues in a given district.

As for the case of homogeneous groups, we start by studying the role played by military colleagues in non-hierarchical groups. In order to do this, we first consider the whole set of workers placed in the same district at a given month as a flat or non-hierarchical team. Proposition (5) predicts that having a military colleague should be associated with a higher performance for civilian tax collectors in larger groups than in smaller ones.

We test this hypothesis both including a dummy variable that takes value 1 when there is at least one military in the group mil_coll and 0 otherwise, and with a discrete variable which gives the number of military colleagues in the district N_mil_coll. The regression analysis includes each of these variables interacted with the number of colleagues in the team, in two different equations. The first of them is given by:

$$Y_{ikdmt} = \alpha_{i7} + \beta_{7a} mil\_coll_{idmt} \times colleagues_{idmt} + \beta_{7b} mil\_coll_{idmt} + \beta_{7c} colleagues_{idmt} + \delta_7 X_{ikdmt} + \varphi_{d7} + \lambda_{m7} + \phi_{t7} + \epsilon_{ikdmt}, \quad (2.19)$$

and the second is:

$$Y_{ikdmt} = \alpha_{i8} + \beta_{8a} N\_mil\_coll_{idmt} \times colleagues_{idmt} + \beta_{8b} N\_mil\_coll_{idmt} + \beta_{8c} colleagues_{idmt} + \delta_8 X_{ikdmt} + \varphi_{d8} + \lambda_{m8} + \phi_{t8} + \epsilon_{ikdmt}. \quad (2.20)$$

The results for each of these regressions are shown respectively in columns (1) and (2) of table 2.5. Both the coefficients on the interactions, $\beta_7 a$ in column (1) β_{8b} in column (2) are positive and significant. This piece of evidence is consistent with the theoretical prediction of the average effect of having a military colleague being larger in larger groups, expressed in proposition 5.

Interestingly, if we compare the coefficients on the two interaction terms we see that β_{8a}, the coefficient on the interaction containing N_mil_coll is smaller in size

than β_{7a}, the coefficient on the interaction containing the dummy *mil_coll*. This finding is consistent with a trivial implication of the model: giving the concavity of the expected highest order statistic Y_k on the number of military k and the constant cost of between-type communication c_o, a second military colleague should contribute less to the expected performance of civilian tax collectors than a first military colleague. Also, the size of these coefficients is not far from the average contribution to performance of an extra civilian colleague, and so these results are quantitatively coherent with the mechanism suggested by the model.

All the previous regressions took only the performance of the civilian tax collectors as the dependent variable. In order to study the relationship between having a military colleague and the performance of military tax collectors we need to extend this sample to the whole set of ACs, including also those who come originally from the army. Proposition 6 in the theoretical model predicts that the effect of having a military colleague should be more positive for military tax collectors than for civilian ones. The following two regressions are used to test this hypothesis:

$$Y_{ikdmt} = \alpha_{i9} + \beta_{9a} military_i \times mil\_coll_{idmt} + \beta_{9b} military_i + \beta_{9c} mil\_coll_{idmt} + \delta_9 X_{ikdmt} + \varphi_{d9} + \lambda_{m9} + \phi_{t9} + \epsilon_{ikdmt}, \quad (2.21)$$

and

$$Y_{ikdmt} = \alpha_{i10} + \beta_{10a} military_i \times N\_mil\_coll_{idmt} + \beta_{10b} military_1 + \beta_{10c} N\_mil\_coll_{idmt} + \delta_{10} X_{ikdmt} + \varphi_{d10} + \lambda_{m10} + \phi_{t10} + \epsilon_{ikdmt}. \quad (2.22)$$

The results for these regressions are shown respectively in column (3) and (4) of table 2.5. The coefficients associated with the interaction terms, β_{9a} and β_{10a}, while positive as predicted by 6, are not statistically significant. One of the potential explanations for the lack of significance of these coefficients is the low number of observations in which a military AC works with a military of any kind in the same district and at the same time.[64]

Heterogeneous and hierarchical groups

This section develops the analysis of the relationship between the individual performance of civilian workers and having military colleagues, taking into account the hierarchical structure of the groups of workers placed in each district. The first part of the analysis corresponds to the association between the performance of civilian tax collectors and the average size of the layer in which the military colleague is placed. The second part of the analysis focus on within-layer dynamics, concretely on how the number of colleagues in a given layer affects the relationship between having a military colleague in that same layer and the individual performance of civilian workers.

[64] In our sample there are only 33 observations in which one of the military ACs has a military colleague of any kind in her group. The coefficient associated to having a military DC is positive (6.66) but does not reach statistical significance either.

	(1) perf	(2) perf	(3) perf	(4) perf
mil_coll× colleagues	0.114*			
	(0.065)			
N_mil_coll × colleagues		0.063**		
		(0.031)		
military×mil_coll			2.480	
			(2.726)	
military×N_mil_coll				2.752
				(2.961)
colleagues	0.199**	0.192***		
	(0.0779)	(0.073)		
military			-0.002	-0.239
			(1.156)	(1.146)
mil_coll	-0.775		0.388	
	(1.022)		(0.573)	
N_mil_coll		-0.663		0.102
		(0.738)		(0.382)
Controls	Yes	Yes	Yes	Yes
District FEs	Yes	Yes	Yes	Yes
Financial_yr FEs	Yes	Yes	Yes	Yes
Month FEs	Yes	Yes	Yes	Yes
Individual FEs	Yes	Yes	No	No
Observations	6935	6935	7105	7105

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.5 – Pooled OLS, heterogeneous groups without considering hierarchy.

For the study of cross-layer results, proposition 8 in the theoretical model predicts that if the effect of having military colleagues in one layer is negative and this is positive in other layers, the negative effect must happen in the layer with the smallest number of colleagues. In order to test for this hypothesis in the data, we estimate three linear equations, one corresponding to each layer of the hierarchical group. For layer 1 or the *DC* layer:

$$Y_{ikdmt} = \alpha_{i11} + \beta_{11} DC\_mil\_coll + \delta_{11} X_{ikdmt} + \varphi_{d11} + \lambda_{m11} + \phi_{t11} + \epsilon_{ikdmt}, \quad (2.23)$$

for layer 2 or the *ACs* layer:

$$Y_{ikdmt} = \alpha_{i12} + \beta_{12} AC\_mil\_coll + \delta_{12} X_{ikdmt} + \varphi_{d12} + \lambda_{m12} + \phi_{t12} + \epsilon_{ikdmt}, \quad (2.24)$$

and for layer 3 or the *other workers* layer:

$$Y_{ikdmt} = \alpha_{i13} + \beta_{13} other\_mil\_coll + \delta_{13} X_{ikdmt} + \varphi_{d13} + \lambda_{m13} + \phi_{t13} + \epsilon_{ikdmt}. \quad (2.25)$$

The results for regressions (2.23), (2.24) and (2.25) are respectively shown in columns (1), (3) and (5) of table 2.6. Here one can see how the negative and significant coefficient β_{11}, compared with the positive —although non-statistically significant—values of β_{a12} and β_{13} support the validity of proposition 8.

Also interestingly, β_{11} the coefficient on DC_mil_coll, with a value -2.17 would correspond to $-c_o$ in the theoretical model, under the assumption of the knowledge of a military DC being equally valuable for tax collection as that of a civilian DC.

The analysis of the within-layer dynamics help to understand why the variables for having a military AC colleague or a military 'other worker' do not have a statistically significant coefficient, while in fact these do seem to matter for the performance of civilian tax collectors. As predicted by the theoretical model, the relationship between individual performance and having a military colleague in each of these layers will depend on the number of workers that the layer has in the corresponding group.

The general mechanism from the model with heterogeneous workers and hierarchy predicts that the contribution of a military colleague placed in a given layer to the performance of those ta collectors in his group should be increasing on the layer's size, see proposition 7. In order to test this in layer 2, we introduce an interaction term between the number of AC colleagues and a dummy which takes value one when there is a military AC in the group, and estimate equation:

$$\begin{aligned} Y_{ikdmt} = \alpha_{i14} + \beta_{14a} AC\_colleagues_{idmt} \times AC\_mil\_coll_{idmt} + \beta_{14b} AC\_colleagues_{idmt} \\ + \beta_{14c} AC\_mil\_coll_{idmt} + \delta_{14} X_{ikdmt} + \varphi_{d14} + \lambda_{m14} + \phi_{t14} + \epsilon_{ikdmt}. \quad (2.26) \end{aligned}$$

For layer 3, we equivalently introduce an interaction term between the number of 'other workers' and the number of military colleagues in the 'other workers' layer, and estimate equation:

$$\begin{aligned} Y_{ikdmt} = \alpha_{i15} + \beta_{15a} AC\_colleagues_{idmt} \times AC\_mil\_coll_{idmt} + \beta_{15b} AC\_colleagues_{idmt} \\ + \beta_{15c} AC\_mil\_coll_{idmt} + \delta_{15} X_{ikdmt} + \varphi_{d15} + \lambda_{m15} + \phi_{t15} + \epsilon_{ikdmt}. \quad (2.27) \end{aligned}$$

The results from the estimation of these two equations are respectively shown in column (3) and column (5) of table 2.6. The two coefficients corresponding the interactions β_{14a} and β_{15a} are both positive and significant, as predicted by the theoretical model.

If the regressions in columns (2), (3), (4) and (5) of table 2.6 are run on the sub-sample of AC civil servants with at least one colleague of the corresponding type of colleagues (AC or 'other', depending on the regression), the coefficient on AC_mil_coll in column (2) becomes closer to 0, while the rest of the coefficients of interest increase their size and their level of significance, but the differences are very small.

After studying the relation between different team compositions and individual performance theoretically, and testing that the main predictions hold empirically in our

	(1) perf	(2) perf	(3) perf	(4) perf	(5) perf
DC_mil_coll	-2.170*				
	(1.185)				
AC_mil_coll		1.483	-1.190		
		(1.220)	(1.478)		
AC_mil_coll×AC_colleagues			0.846*		
			(0.510)		
other_mil_coll				1.104	-1.042
				(0.985)	(0.912)
other_mil_coll×other_colleagues					0.126***
					(0.037)
AC_colleagues		-0.287	-0.308		
		(0.314)	(0.314)		
other_colleagues				0.222***	0.241***
				(0.068)	(0.070)
Controls	Yes	Yes	Yes	Yes	Yes
District FEs	Yes	Yes	Yes	Yes	Yes
Financial_yr FEs	Yes	Yes	Yes	Yes	Yes
Month FEs	Yes	Yes	Yes	Yes	Yes
Individual FEs	Yes	Yes	Yes	Yes	Yes
Observations	5976	5976	5976	5976	5976

Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.6 – Pooled OLS, results for the case of heterogeneous groups, considering hierarchy.

study of Pakistan tax collectors, in the next section we use the suggested mechanism to analyze optimal team composition, from the point of view of an organization which wishes to maximize its expected revenue.

2.5 The problem of the organization: the optimal allocation of workers across different teams

While a full-fledged theoretical analysis of the problem of the organization is out of the scope of this paper, this section illustrates the kind of results that the suggested mechanism can offer for the optimal allocation of workers in contexts in which knowledge spillovers are important for individual performance.

One of the characteristics which makes the suggested mechanism particularly powerful from an economic point of view is that several of the results offer the organization a free lunch, with a different allocation of the same workers increasing aggregate performance, without incurring in higher costs.

The problem of the organization is to choose the optimal number of total workers and the number of workers of each type to hire, in order to maximize total expected

revenue, given by the expected aggregate production net of wages.

Together with dividing the analysis between homogeneous and heterogeneous teams in terms of workers' types, and between non-hierarchical and hierarchical groups, we will considered both the case of organizations with just one team and of organizations composed of multiple teams. Wages are considered exogenous.

2.5.1 Optimal aggregate performance with homogeneous teams

The problem of an organization with homogeneous teams is to choose the number of workers that maximizes its aggregate performance, net of wages. We assume that the organization knows the optimal solution to the problem of individual workers, who choose with how many colleagues to communicate with.

Homogeneous and non-hierarchical teams

An exogenous wage w is paid to each ex-ante identical worker. For a wage lower than the individual expected performance in a team in which each agent talks to the optimal number of workers $\hat{h}$,[65] it will be optimal to hire an infinite number of workers. Hence, the problem is only interesting for the case of $w > pX_{\hat{h}+1} - \hat{h}c_s$. In this case, hiring a number of workers m higher than $\hat{h}+1$ will never be optimal for the organization. This implies that in order to solve the maximization problem of the firm we do not need to take into account the optimization problem of individual workers, as given a number of group members equal or lower than $\hat{h}+1$ each of them will find it optimal to communicate with everyone else. For the case of an organization composed of only one team, the maximization problem is given by:

$$\begin{aligned} \underset{m}{\text{maximize}} \quad & m(pX_m - (m-1)c_s - w), \\ \text{subject to} \quad & w > pX_{\hat{h}+1} - \hat{h}c_s, \end{aligned} \tag{2.28}$$

Notice that the constraint directly implies $m \leq \hat{h}+1$. The first order condition is:

$$mp\frac{\partial X_m}{\partial m} + pX_m - (2m-1)c_s - w = 0 \tag{2.29}$$

The first term gives the contribution of the worker to the team in terms of informational gains, the second term corresponds to his individual production in a team with m workers, while (2m-1) indicates the number of extra communication costs incurred by the members of the team with the arrival of an extra colleague. Hence, the interpretation of this FOC is simply that the optimal number of workers is established at the point m^* at which the marginal contribution of worker m^* to aggregate performance is equal to its wage. As long as w is low enough as for it to be optimal

[65] The individual expected performance in a team in which each agent talks to the optimal number of workers is equal to the marginal contribution of hiring an extra worker in a team of size $m \geq \hat{h}+1$.

to hire a positive number of workers,[66] the concavity of X_m with respect to the sample size implies that under pretty general conditions a unique interior solution to the problem will exist, with the optimal size of the team given by $\hat{m}$, the highest natural number smaller or equal than the optimal m^*.[67]

Naturally, in this simplified environment, if it is optimal for an organization to hire a team of $\hat{m}$ workers, it will also be so to hire a larger number of equal teams. When thinking about an organization with several teams, a potentially interesting question is whether in a context in which only a finite number of workers is available, such that the organization cannot distribute its work force into teams with the optimal size, it is preferred to hire balanced or unbalanced teams. This is better illustrated with an example, for the case in which the optimal number of workers per team is $\hat{m}$, but the number of available workers M is such that $\hat{m} < M < 2\hat{m}$.

Assume that the optimal number of team members is 3 and the firm has 4 workers available. The difference in expected aggregate performance between combining these workers in two teams of 2 workers each or combining them into two different teams with respectively 3 and 1 members is given by $p(X_2 - X_1) + 3p(X_2 - X_3) + 2c_s$. While, as long as the organization prefers teams with either 1 or 2 workers than an empty team there is not a general answer to this question, we can say that balanced teams are more preferred for a higher concavity of X_m and for a higher cost of communication c_s. These two factors also contribute positively to few larger teams giving the organization a higher gain relative to having a larger number of smaller teams. In this case, we do find a general solution:

Proposition 9. *For balanced teams —in terms of their number of workers —each of size $m < m^*$, the organization always prefers to have a smaller number of larger teams than a larger number of smaller teams.*

It is easy to check that in the previous example it is always preferable for the organization to have 2 teams with 2 workers each than 4 teams with 1 worker each. The difference in expected aggregate performance between the first and the second configuration is given by $4p(X_2 - X_1) - 4c_s$. This is always larger than 0 as $p(X_2 - X_1) > c_s$ follows directly from the concavity of X_m and the solution of the individual worker who finds it optimal to communicate with at least 3 colleagues, as these imply both $p(X_3 - X_2) < p(X_2 - X_1)$ and $p(X_3 - X_2) > c_s$. The same reasoning extends this result for teams with a larger number of members.

Homogeneous and hierarchical teams

When hierarchy is introduced, we consider that those workers in the first layer of the hierarchy (non-producers) get the exogenous wage w_A, and those in the second layer of the hierarchy (producers) the wage w_B. The problem of the organization is now to choose the optimal number g_1 of workers in the first layer and l_1 producers in the second layer.

[66] It is easy to show that under very general conditions w can satisfy both been low enough such that some workers are hired and high enough such that hiring an infinite number of workers is not optimal.

[67] Similarly to what happened in the case of communication between producers, it does not make sense to consider that the firm can hire a non-integer number of workers.

The only constraint we need to impose for the organization to not find it optimal to hire an infinite number of non-producers is for $w_A > 0$, the marginal contribution to aggregate performance of an extra non-producer arriving to a team in which every producer is already communicating with all the non-producers he wants, h_a.

Similarly to in the previous scenario without hierarchy, for an organization composed of just one team to not find it optimal to hire an infinite number of producers, it must be the case that a producer's wage w_B is smaller than her marginal contribution to aggregate performance if she arrives to a team in which every producer is already communicating to the optimal number of same-layer colleagues h_b, $w_b > qpX_{h_a} - h_a c_s + (1-q)pX_{h_b} - (h_a - 1)c_s$. Notice that this will imply it will never be optimal for the organization to hire a number of non-producers g_1 higher than h_a or a number of producers l_1 higher than h_b. Under this restriction, all workers in the team will find it optimal to communicate with each other. The problem of the organization is then given by:

$$\begin{aligned} \underset{g_1, l_1}{\text{maximize}} \quad & l_1\{qpX_{g_1} - g_1 c_s + (1-q)pX_{l_1} - (l_1 - 1)c_s - w_B\} - g_1 w_A. \\ \text{subject to} \quad & w_a > 0, \\ & w_b > qpX_{h_a} - h_a c_s + (1-q)pX_{h_b} - (h_a - 1)c_s, \end{aligned} \tag{2.30}$$

with the constraint directly implying $g_1 \leq h_a$ and $l_1 \leq h_b$. The first order conditions are respectively:

$$\begin{aligned} & (qpX_{g_1} - g_1 c_s) + l_1(1-q)p\frac{\partial X_{l_1}}{\partial l_1} + (1-q)pX_{l_1} - (2l_1 - 1)c_s - w_B = 0, \\ & \textit{and} \\ & \left(qp\frac{\partial X_{g_1}}{\partial g_1} - c_s\right) - w_A = 0. \end{aligned} \tag{2.31}$$

The interpretation of these FOCs tells us that the optimal number of workers in each layer is found when the marginal contribution to aggregate performance of an extra worker in a given layer equals the corresponding wage. As long as the wages w_A and w_B are low enough for a positive number of workers to be hired in each layer, the concavity of X_{l_1} and X_{g_1} ensures the existence of a unique interior solution under pretty general conditions. As one would expect, from the FOC for g_1 we see that the optimal number of workers in layer 1 is increasing on the number of producers, l_1.

As in the previous case without hierarchy, in a context in which the available number of workers does not allow the firm to distribute their employees in teams with the optimal structure, this model allows for the study of the optimality of balanced versus unbalanced, or larger versus smaller teams, as well as the relative number of workers in each layer. As the main object of this paper is group diversity, we will not dedicate more attention to the study of these questions here, but proceed to the analysis of the problem of the organization with heterogeneous teams.

2.5.2 Aggregate performance with heterogeneous teams

In this section we abstract from explicitly describing the general maximization problem of an organization hiring both type 1 and type 2 workers. Instead, we will assume that both types of workers are symmetric for the production process, in the sense of being equally productive in isolation, having the same within-type and between-type costs of communication, and receiving the same wage when placed in the same layer, and we will focus on their optimal allocation. In particular, we are interested in characterizing when having both types of workers together in the same team is better for aggregate performance than having a fully homogeneous group, and whether a symmetric allocation of workers in a given team results from workers' symmetry.

After answering these questions, we will focus on analyzing how an organization can optimally allocate a finite number of workers from the less numerous type into a finite number of otherwise homogeneous teams.

Heterogeneous and non-hierarchical teams

Under the assumption of both types being symmetric with respect to production, $p = 1-p = 0.5$, $f_x(x), \sim f_y(y)$, and the exogenous wage w is the same for type 1 and type 2 workers. Trivially, under these conditions, expected total performance is the same for a team with m type 1 workers and k type 2 workers and for a team with k type 1 workers and m type 2 workers, for every m and k. The expected aggregate production of a team with m type 1 workers and k type 2 workers is simply:

$$E[Z(m,k)] = mE[z_1(m,k)] + kE[z_2(m,k)]. \tag{2.32}$$

The exogenous wage for each type of worker being the same implies that as long as the total size of the group $N = m + k$ is kept constant, the analysis of different combinations of type 1 and type 2 workers can be developed without considering wages.[68]

An interior solution with $m, k > 0$ will exist, with a combination of both types of workers in the same team being optimal whenever the two following conditions hold simultaneously, $E[Z(N-1,1)] > E[Z(N,0)]$ and $E[Z(1,N-1)] > E[Z(0,N-1)]$. Under the assumption of full symmetry across types, if one of these conditions hold, the other will hold as well. In general, these conditions will be respectively satisfied when $c_o < \frac{N[p(X_{N-1}-X_N)+(1-p)Y_1]}{2(N-1)}$ and $c_o < \frac{N[pX_1-(1-p)(Y_{N-1}-Y_N)]}{2(N-1)}$, as long as the numerator of the right hand size is larger than zero (N > 1). In general, the following result holds:[69]

[68] From now on, N is taken to be fixed and even, in order to allow for the case $m = k$

[69] Notice that this result holds also without the assumption of full symmetry, in which case the definition of a 'low enough' cost of communication will be strongly determined by the value of p, and the distributions of f_x and f_y. Naturally, if the value and shapes of this parameter and these distributions are relatively extreme, with one of the types being much better for production than the other, an interior solution might only exist for very low values of c_o, or in very large teams.

Proposition 10. *For a given size team $N \geq 2$, a low enough between-type cost of communication will guarantee that an interior solution is optimal, with a team composed of a positive number of both type 1 and type 2 workers maximizing expected aggregate performance.*

Under the assumption that the between-type cost of communication c_o is low enough given team size N as for an interior solution to exist, the first natural step is to explore the optimal combination of workers of each type. While the problem of finding the optimal number of type 1 workers m and type 2 workers k in a team of fixed size N is analytically solvable, the closed form solution is too complicated for illustrative purposes. A simpler and still interesting question is whether the expected aggregate production of a team with m and k workers of each type increases or decreases if one of the type 1 workers is substituted by a type 2 one.

Answering this question amounts to compare the expected production of a team with respectively m and k workers of each type with that of a team composed by $m-1$ type 1 workers and $k+1$ type 2 workers. With the expected performance of each worker given by (2.4) and (2.5), the expected production for the whole team in each case is given by:

$$E[Z(m,k)] = mE[z_1(m,k)] + kE[z_2(m,k)],$$

and

$$E[Z(m-1,k+1)] = (m-1)E[z_1(m-1,k+1)] + (k+1)E[z_2(m-1,k+1)]$$

.

Subtracting the first expression from the second one gives $E[Z(m-1,k+1)] - E[Z(m,k)]$ as:

$$N[p(X_{m-1} - X_m) + (1-p)(Y_{k+1} - Y_k)] + 2(k-m+1)c_o. \tag{2.33}$$

This result shows that for given values of m and k there are two opposed effects determining if getting a type 2 colleague in the place of a type 1 will or will not improve the team's expected performance: the information added by this substitution and the cost of communication go in opposite directions. What determines which of these two effects dominates? We analyze this problem by considering three different cases, according to the relative values of m and k:

1. $m = k$: In this case the comparison among the expected performance under the two different team compositions is reduced to $N[p(X_{m-1} - X_m) + (1-p)(Y_{k+1} - Y_k)] + 2c_o$. As the between-type cost of communication increases, an unbalanced team ($m \neq k$) is preferred to a balanced one ($m = k$).[70]

2. $m >> k$: in this case there is an initial majority of type 1 workers. Substituting one of them by a type 2 worker will improve the expected performance of the full team if:

[70] Whenever $\frac{N[p(X_{N-1}-X_N)+(1-p)Y_1]}{2(N-1)} > c_o > \frac{N[p(X_{m-1}-X_m)+(1-p)(Y_{k+1}-Y_k)]}{2}$ there will an optimal interior solution with $m \neq k$.

$$c_o < \frac{N[p(X_{m-1} - X_m) + (1-p)(Y_{k+1} - Y_k)]}{2(m-k-1)}.$$

Everything else equal, lower costs of communication will make it more preferable to hire a type 2 worker for a team with a majority of type 1 workers.

3. $m << k$: in this case, the sign of the inequality reverts, with the condition for hiring a type 2 worker being preferred over hiring a type 1 worker becoming:

$$c_o > \frac{N[p(X_{m-1} - X_m) + (1-p)(Y_{k+1} - Y_k)]}{2(m-k-1)}.$$

Everything else equal, higher between-type costs of communication will make it more preferable to hire a type 2 worker for a team with a majority of type 2 workers.

Basically, lower between-type costs of between-type communication make groups which are closed to balanced in terms of the proportion of workers of each type more preferred. Equivalently, higher costs of between-type communication increase the optimality of extreme teams, with a large number of workers of one type and only a few members of the other type. As we have seen, for a large enough c_o the optimal team is homogeneous.

From now on, the analysis will focus on the case in which c_o falls between these two extremes, with the optimal allocation having a larger number of workers of a given type and a lower number of the other. Under full symmetry any type can be the most numerous.[71] For the rest of the section we will work with the case $m >> k$.

The number of agents optimally chosen by the organization is such that every agent will communicate to all of her colleagues.[72] The initial allocation of workers is given by the optimization problem of the organization with homogeneous teams, such that the team is currently composed by $m = \hat{m}$ type 1 workers —see maximization problem (2.28). We now proceed to characterize under which conditions the expected performance of such a team is lower than that of a team with $m-1$ type 1 workers and one type 2 worker. As before, the cost of within type communication c_s is normalized to 0. With the expected performance of the homogeneous team given by:

$$E[Z(m,0)] = m(pX_m) \tag{2.34}$$

and the expected performance of the heterogeneous team being

$$E[Z(m-1,1)] = (m-1)(pX_{m-1} + (1-p)Y_1 - c_o) + (pX_{m-1} + (1-p)Y_1 - (m-1)c_o), \tag{2.35}$$

the expected performance of the heterogeneous team is larger than that of the homogeneous team if the following condition is satisfied:

$$m[p(X_{m-1} - X_m) + (1-p)Y_1] > 2(m-1)c_o. \tag{2.36}$$

[71] Trivially, with the wage being equal for both types, if c_o falls in such an interval and there is not symmetry in production for the two types of workers, the optimal allocation will have a higher number of members from the most-productive type, and a smaller number of workers from the less productive one.

[72] As in the previous section, this will be the case if the exogenous wages are high enough.

The concavity of X_m implies that the left hand size of the inequality grows with m at an increasing rate, while the right hand side grows linearly with m. There will be a critical m_c, such that homogeneous teams are preferred for $m < m_c$ and heterogeneous teams are preferred for $m > m_c$. In summary, everything else equal the optimality of having either a fully homogeneous or a heterogeneous team with one type 2 depends directly on the size of the team $N = m$, with heterogeneous teams becoming more preferable as this rises.

In a situation in which the distribution of the current number of workers of each type in the team is not optimal, with $m > \hat{m}$ and $k < \hat{k}$, always with $m+k = N$, expected team production increases with the substitution of some of the type 1 workers by type 2 ones. How many workers is it optimal to substitute? A natural question is to ask whether a second substitution of a type 1 worker by a type 2 worker will increase expected team production more or less than the first substitution. Answering this question amounts to compare $\{E[Z(m-2,k+2)] - E[Z(m-1,k+1)]\}$-$\{E[Z(m-1,k+1)] - E[Z(m,k)]\}$, which after some algebra results in:

$$N\{p[(X_{m-2} - X_{m-1}) + (X_m - X_{m-1})] + (1-p)[(Y_{k+2} - Y_{k+1}) + (Y_k - Y_{k+1})]\} + 4c_o. \tag{2.37}$$

The first term of the equation is negative, so for low enough c_o the full condition will be negative, meaning that for low costs of between-type communication, the expected team performance will increase more with the first substitution of a type 1 worker for a type 2 than with a second substitution. Under these conditions, a first substitution being optimal does not necessarily imply that a second substitution will be so. However, notice that each new substitution reduces more the total between-type cost of communication than the previous one. This implies that if c_o is large enough as to make condition (2.37) larger than 0, when a first substitution of workers of different types increases the team's expected performance, a second substitution will increase it even more. It is straightforward to check that in this case, a third substitution will increase the team expected performance more than the second one, and so on. In this case the optimal team is homogeneous with only type 2 workers, a contradiction:

Proposition 11. *If the cost of between-type communication is low enough for an interior solution to be optimal, whenever the team is not in the optimal allocation and substituting a type 1 worker for a type 2 worker increases expected team performance, a second substitution of a type 1 worker by a type 2 worker must increase expected team performance by less than the first substitution does.*

This will have important implications for allocation problems, such as an organization introducing type 2 workers into otherwise homogeneous type 1 teams. Take for example the case in which an organization with two homogeneous teams of size N has to choose how to distribute two type 2 workers. The following result is obtained:

Proposition 12. *If an organization composed by multiple teams has to place two type 2 workers into otherwise homogeneous, type 1 teams with the same number of workers, it will maximize expected aggregate performance by placing each of these workers in a different team instead of placing both of them together in the same one.*

This result can be generalized to a larger number of substitutions: having a more balanced amount of type 2 workers across teams mainly populated by type 1 workers

is better for aggregate performance than concentrating type 2 workers in a few groups.

In the case of tax collection in the Pakistan civil services this result implies that if two military ACs or two military 'other workers' must be placed in the same layer of two equal groups, it is better for aggregate performance to place each of them in a group than to place them together in the same one.

While this result might seem trivial, it is particularly interesting because the solution of an equivalent problem with hierarchical teams will be the opposite: placing both workers in the same group will be optimal for aggregate performance.

Heterogeneous and hierarchical teams

For a hierarchical team with two layers of size g and l, respectively with g_1 and g_2 type 1 and type 2 workers in layer 1 and l_1 and l_2 producers of each type in layer 2, expected team production is given by:

$$E[Z(g_1, g_2; l_1, l_2)] = l\{q[pX_{g_1} + (1-p)Y_{g_2}] + (1-q)[pX_{l_1} + (1-p)Y_{l_2}]\} - [l_1(g_2 + l_2) + l_2(g_1 - l_1)]c_o \quad (2.38)$$

The gain in expected team performance from having an extra type 2 worker in the place of one of the g_1 type 1 workers in layer 1 is given by $E[Z(g_1 - 1, g_2 + 1; l_1, l_2)]$-$E[Z(g_1, g_2, l_1, l_2)]$ as

$$lq[p(X_{g_1-1} - X_{g_1}) + (1-p)(Y_{g_2+1} - Y_{g_2})] + (l_2 - l_1)c_o. \quad (2.39)$$

The interpretation of this condition tells us that the gain —or loss —in expected performance before considering costs of communication, equal for every individual independent of her type, is multiplied by the total number of individuals l.[73] Naturally, this implies that a substitution of a type 1 worker by a type 2 worker in the layer of non-producers will increase the team's expected performance more the larger the number of type 2 producers in the group. If the first term in the equation is positive, the gain in expected performance derived from this substitution is increasing on q, and *vice versa*. Similarly, the gain in expected performance from having an extra type 2 producer instead of a type 1 one in layer 2, resulting from $E[Z(g_1, g_2; l_1 - 1, l_2 + 1)]$-$E[Z(g_1, g_2; l_1, l_2)]$ is given by:

$$l(1-q)[p(X_{l_1-1} - X_{l_1}) + (1-p)(Y_{l_2+1} - Y_{l_2})] + [2(l_2 - l_1 + 1) + g_2 - g_1]c_o. \quad (2.40)$$

Again, the gain in expected performance before considering communication costs is the same for every producer, independently of her type. If this gain is positive, it is

[73] Communication costs decrease by l_2, as all type 2 producers save one c_o each, and similarly increase by l_1, as all type 1 producers spend an extra c_o.

increasing on $1-q$ or equivalently decreasing on q, and vice versa.[74]

Comparing the gain in expected team performance from substituting a type 1 colleague by a type 2 in layer 1 with that derived from the impact of the same substitution taking place in layer 2 equates to subtract condition (2.40) from (2.39), finding $E[Z(g_1-1,g_2+1;l_1,l_2)]$-$E[Z(g_1,g_2;l_1-1,l_2+1)]$, which results in:

$$l\{q[p(X_{g_1-1}-X_{g_1})+(1-p)(Y_{g_2+1}-Y_{g_2})]-(1-q)[p(X_{l_1-1}-X_{l_1})+(1-p)(Y_{l_2+1}-Y_{l_2})]\} + [l_1-(l_2+1)+g_1-(g_2+1)]c_o \quad (2.41)$$

Under full symmetry, also across layers ($q=p=1/2$) and with $g_1=l_1=g_2=l_2$ this condition is just equal to $-2c_o<0$, and so it is better for aggregate production to substitute a type 1 producer by a type 2 one than to make this same substitution for layer 1 non-producers. In general, everything else equal higher g_1 and lower g_2 make the condition more positive, while higher l_1 and lower l_2 make the condition more negative.

The effect of q on the optimality of substituting a type 2 worker into layer 1 instead of substituting a type 2 producer into layer 2 depends on the sign of the aggregate gain in expected performance without considering communication costs. The effect is positive if the informational gain is positive with the substitution happening in any of the two layers, it is negative if this is negative in both layers, and the value of $q\in(0,1)$ does not matter if this is positive in one of the layers and negative in the other.

In the context of Pakistan civil services this would trivially mean that if possible, it would be better to place military colleagues as ACs or 'other colleagues' than as DCs.

Having multiple hierarchical teams in the organization.

Finally, it is interesting to explore if the substitution of a type 1 worker by a type 2 worker in each of the two layers adds something to the results from making this substitution in each of them separately. This amounts to compare $E[Z(g_1-1,g_2+1;l_1,l_2)]$-$E[Z(g_1,g_2;l_1,l_2)]$+$E[Z(g_1,g_2;l_1-1,l_2+1)]$-$E[Z(g_1,g_2;l_1,l_2)]$ with $E[Z(g_1-1,g_2+1;l_1-1,l_2+2)]$-$E[Z(g_1,g_2;l_1,l_2)]$. The results from these two expressions are identical in terms of the gain in expected team performance without considering communication costs. However, substituting a type 1 by a type 2 worker in both layers of the same team implies a higher saving in communication costs, in concrete $2c_o$. This implies the following result:

Proposition 13. *When substituting two same-type workers into different layers of two exactly equal hierarchical teams, aggregate performance increases more when both workers are introduced into the same team than they go to different groups..*

[74] In this case the aggregate costs of communication increases by g_1, as an extra type 2 producer has to communicate with the g_1 workers in layer 1, and it is reduced by g_2, as one type 1 producer less communicates with the type 2 non-producers in this same layer. This also increases by $2(l_1-1)$, as the now l_1-1 type 1 producers communicate with an extra type 2 producer and this extra type 2 producer with them, and it decreases by $2l_2$, as one type 1 producer less communicates with the type 2 producers, and the type 2 producers communicate with one type 1 producer less.

This will imply that when allocating a few type 2 workers into teams which are mostly populated by type 1 workers, it is better to place them in different layers of the same team, building groups with at least two type 2 workers each, than to keep the type 2 workers each in a different team, as was the case for an organization composed by non-hierarchical teams.[75] The reason is that while the saving of c_o also takes place in non-hierarchical teams, in these kind of groups the aggregate gain in information or knowledge —without considering communication costs—is higher when the workers are introduced into different teams than when they are introduced into the same one, while for the case of hierarchical teams the aggregate gain in knowledge is the same in both cases.

In the context of the Pakistan civil services this would imply that if we have to allocate a military DC, a military AC and a military 'other worker' into three districts currently composed by civilian tax collectors, it would be better for aggregate performance to introduce the three military workers in the same group than to allocate them in any other way.

2.6 Conclusion

This paper proposes, develops and tests a theoretical mechanism for the study of the relationship between group diversity and performance, in contexts in which the nature of the complex task faced by individual workers makes knowledge spillovers particularly important for its successful completion.

Group size plays a crucial role in the suggested mechanism, as the knowledge of similar workers becomes redundant as their number increases. This makes the inclusion of diverse colleagues more beneficial for performance in larger horizontal groups, and in larger layers in the case of hierarchical teams.

In the empirical part of the paper, we use the existence of a quota for military workers in the Pakistan Administrative Services to study whether their presence in groups and layers of different characteristics is associated to the performance of civilian tax collectors in the same way as the theoretical model suggests. The main predictions are found to hold both for homogeneous and heterogeneous groups, and for horizontal and hierarchical teams. In the latter case the findings are coherent with the predictions of the theoretical model both across and within layers.

After deriving the model for individual performance and testing its main predictions empirically, the paper explores aggregate team performance theoretically. The suggested mechanism allows us to propose some simple rules for the allocation of heterogeneous workers into teams, which allow an organization to increase its aggregate production just through rotations of workers, without increasing its labour costs.

The predictions derived from this theoretical model or simple extensions of it, should hold whenever producers organized in a group are trying to solve individual complex or intellectual tasks for which there is an objectively correct or optimal solution, as

[75] This result relates directly to the concept of Redundant Heterogeneity in which Smith 2014 base their findings.

long as we can believe that workers have some capacity to discern what constitutes a good solution to the problems they face and what does not.

As in the suggested mechanism knowledge spillovers affect individual performance through inter-worker communication, a set of workers can be considered a group or team as long as a worker trying to solve a complex task on her own has the possibility of communicating with her colleagues to ask for advise or information. In that case, the mechanism should be at play. Clear examples of such organizations include universities and research centers, political, bureaucratic and administrative teams, and virtually every large enough firm in the private sector.

2.7 Appendix

2.7.1 The structure in layers of a hierarchical group or team.

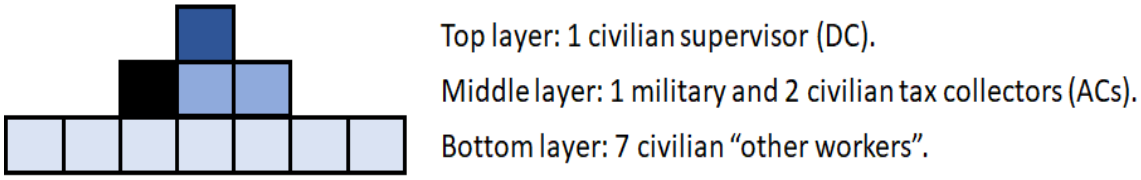


Figure 2.2 – Illustrative example of one team with 11 members, 10 civilians: 1 supervisor or DC, two tax collectors or ACs, and 7 "other workers", and 1 military tax collector (in black).

2.7.2 The main functions of Assistant Commissioners

Pre-1997, the functions carried out by the office of the AC fell under two main heads: Revenue and maintenance of law and order. Post Legal Reforms Act 1997, Local Government Act 2001, and various executive orders, the law and order aspect of the job has mostly been withdrawn and replaced with other miscellaneous responsibilities. The set of miscellaneous activities depends on the prerogative of the government and can change from time to time, however, they are generally allocated to all ACs in Punjab together. There can be spurts of responsibilities like an anti-encroachment drive, organizing activities around Islamic festivals or more general coordination and monitoring activities. Since AC is the linchpin of the government in the tehsil the usual practice is to refer to the AC for any queries. While not exhaustive, the following list contains many of the functions typically assigned to Assistant Commissioners in Punjab:

Official assignments:

- Revenue administration.
- Price control magistracy.
- Coordination with different state departments.
- Monitoring of devolved & non-devolved departments.

Revenue regarding functions:

- Anti-encroachment functions.
- Disposal of judicial cases.
- Monitoring of the progress of revenue officers.
- Periodically checking the revenue record maintained by the patwaris.[76]

[76] A patwari or *rural accountant* is the lowest state functionary in the Revenue Collection system. His or her job encompasses visiting agricultural lands and maintaining record of ownership and tilling, which has historically given them a very large influence in local communities. They have their primary base in rural areas.

- Hearing of service appeals.
- Recruitment of lower revenue field staff.
- Revenue reporting to the higher authorities.

Coordination functions:

- Coordination with Food Department regarding procurement of wheat.
- Coordination with the Agricultural Department regarding monitoring of fertilizers and water courses.
- Inspection of development work carried out by the local government departments.
- Coordination with the Health department regarding inspections and providing support during official campaigns.
- Coordination with the local government regarding conduction of inquiries of outdated death and birth entries.
- Coordination with the Education department regarding inspection of schools and construction of new school buildings.
- Coordination with the Irrigation department during floods.

2.7.3 The Punjab Agricultural Income Tax 1997

Section 4 of AIT Act, 1997 states that every person:

> 1. whose total agricultural income or the total agricultural income of any other person in respect of which he is assessable under this Act, for any income year (hereinafter referred to as the said income year) exceeds the maximum amount[77] which is not chargeable to tax under this Act; *or* (emphasis added)
>
> 2. who himself or any other person on whose behalf he is assessable under this Act, has, during the said income year, cultivated land measuring: (i) fifty acres or more of irrigated land; or (ii) one hundred acres or more of unirrigated land; or (iii) irrigated and unirrigated land the aggregate area of which is equal to or more than fifty acres of irrigated land, one acre of irrigated land being reckoned as equivalent to two acres of unirrigated land, shall file a return of his total agricultural income or the agricultural income of such other person, as the case may be, for the said income year in such form and by such date as may be prescribed.

[77] The Punjab Agricultural Income Tax Rules 2001 states that this threshold is Rs. 80,000.

2.7.4 Origin of the different elements in the theoretical model

The basic structure and ingredients of the model, such that there are two types of workers with information which is more correlated within types than across types, and between-type communication being more costly or difficult than within-type communication draw from Lazear (1999). We introduce two main innovations with respect to his original model.

The first main change is the adaptation of the model to make knowledge spillovers affect individual performance instead of affecting just the aggregate team performance. While a very simple change from a technical point of view, by allowing the model to produce predictions about individual performance, this modification makes the two models able to explain problems of a very different kind.

The second modification deals with the role played by between-type communication, and is deeper in nature. In Lazear's model, the cost of communication does not refer to difficulties in communicating across agents who are intrinsically different, but to the cost of learning the language spoken by those workers of a different type. In his model agents of two different types cannot communicate at all their knowledge or skills unless the workers from one of the two types are bilingual. Then, workers optimally choose whether to pay the cost of becoming bilingual or not, depending on the wage premium the firm would pay them for doing so.[78] In our model, the cost of communication is intrinsically attached to workers' type. It can be interpreted as an element consuming workers' time when they talk to each other, or difficulting the clean communication of their ideas, similarly to the interpretation in Garicano 2000 and is higher between types than within types as in Antràs et al. 2006b. Basically, communication costs worsen the knowledge spillover across colleagues, decreasing individual performance. This makes the model able to explain the effect of combining types of diversity which go further than just the linguistic divergence among workers from different nationalities, such as gender, race, religion, professional background, or political orientation.

As it is common in this stream of the literature,[79] in order to focus on the interrelation between the information and communication existing under a given organizational structure and agents' performance, we will abstract from incentive-based theories and effort considerations, assuming that agents' effort is orthogonal to changes in the composition of the members of the group they belong to. However, as we will see, there is still a place for an implicit role of effort in our model, as the higher cost of between-type communication might be interpreted in part as the outcome of a lower interest or effort being exerted in communicating with workers of a different type. This would arguably be the case if talking to them is considered more demanding for the worker than talking to same-type colleagues.

[78] The main analysis focuses then on different conditions which would actually make one or the other type of workers to optimally pay the cost of becoming bilingual, and the main theoretical predictions are illustrated with statistical facts about the proportion of workers of different nationalities in global firms.

[79] See for example Lazear (1999) or Garicano (2000).

2.7.5 List of assumptions for the theoretical model

This part of the appendix lists explicitly the main assumptions on which the model rests. Most of them, named by A.1 are related to the communication costs across agents.

- A.1.1. The cost of communication (both c_s and c_o) is interpreted as a factor difficulting or worsening the transmission of knowledge.
- A.1.2. While in most of the literature the communication costs are aggregated in the worker being asked, the receiver (see Garicano, 2000; Radner, 1993; Bolton and Dewatripont, 1994), in our paper the cost of communication falls on both workers, both the receiver and the sender. This is consistent with communication among two workers being always bilateral, and happening only if the two parts find it optimal.
- A.1.3. The between-type cost of communication c_o is the same when a type 1 'starts communication' (demanding information) and when a type 2 does. It could be interesting to relax this as an extension of the model.
- A.1.4. The cost of communication is the same across all same-type communications, independently of the layer of the hierarchy in which each worker is placed, and the characteristics of this layer. This assumption greatly simplifies the model, but is probably one of the least likely to hold in real world applications. Relaxing it would make the model versatile to explain a larger variety of dynamics in hierarchical groups. In particular, it could be particularly interesting to consider a potential interaction between the relative position of workers in a hierarchical group and the costs of communication with colleagues in other layers, depending on their type.
- A.1.4. The cost of communicating with a different type agent is higher than the cost of communicating with a same type agent, $c_o > 0$.
- A.1.5. The cost of communicating with a different type worker c_o and the number of different type workers in the group k or m, are low enough as for it to be optimal for an agent to communicate with all the different type agents in her team, respectively $c_o < (1-p)(Y_k - Y_{k-1})$ for a type 1 worker, and $c_o < p(X_m - X_{m-1})$ for a type 2 worker. This assumption is relaxed at some point during the study of hierarchical teams, in concrete for non-producers. Relaxing this assumption for producers would potentially imply the existence of a 'diffusion effect' when a worker of a less numerous type (type 2 in our model) is introduced into a homogeneous or mostly type 1 group. For large groups, this would imply a non-monotonic effect of such a substitution on the performance of type 1 producers, with the positive effect increasing with group size until a certain critical number of type 1 team members $\bar{m}$ and decreasing for $m > \bar{m}$. While the number of producers (tax collectors) in our application (1-7) is probably too small for such a 'diffusion' effect to be at play across workers of different types, it might be worth it to keep this possible effect in mind when interpreting any case study with large groups of producers in light of this model.
- A.2. Conditional on requiring the same level of effort, an agent prefers to

produce more than less.

- A.3. The information or knowledge necessary to produce x_i and output y_i is not overlapping, implying the probability of the task being solved by each of the two types is exclusive, $p = 1 - p$. The implications of relaxing these assumption are quite intuitive.
- A.4. Both types of workers get the same wage when they are placed in the same layer.

2.7.6 The highest order statistic.

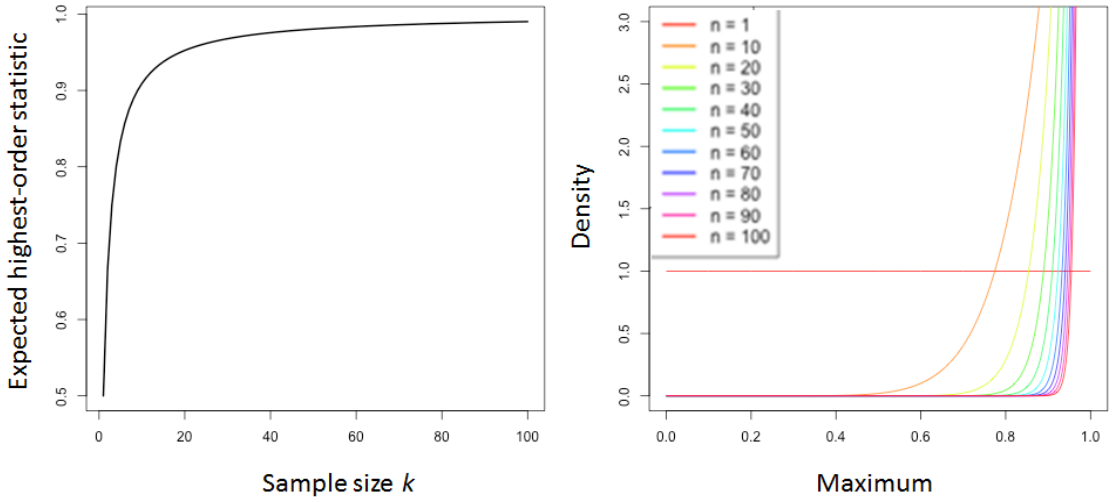


Figure 2.3 – Statistics from a uniform [0,1] distribution. LHS: The expected or average highest order statistic for a sample of size RHS: The probability density function of the expected highest order statistic.

2.7.7 Proof for proposition 5

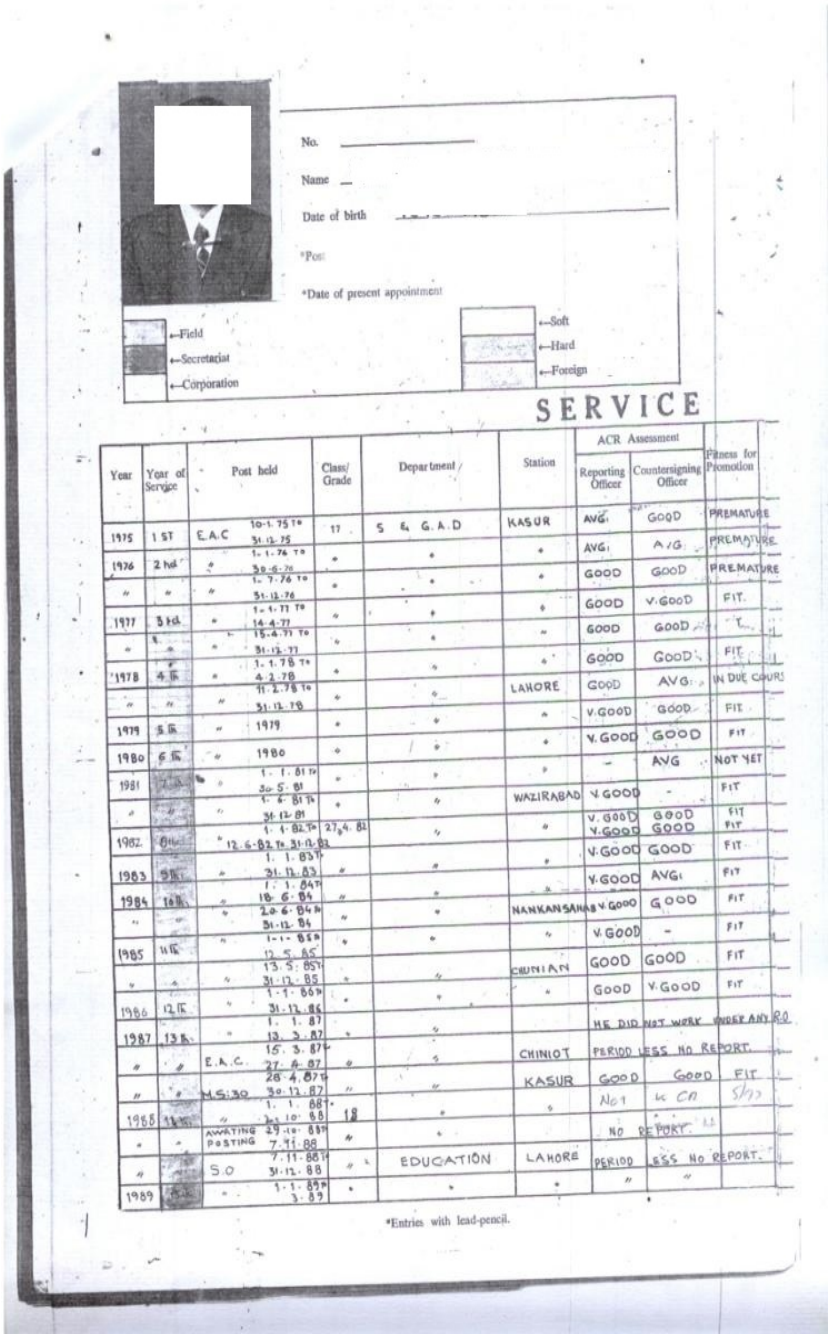
The proof to this proposition follows simply from the concavity of X_m. The difference in the effect on type 1 workers expected performance from substituting a type 1 colleague by a type 2 one, in two teams with the same number of type 2 colleague but of different sizes is given by comparing $E[z_1(m-1,k+1)] - E[z_1(m,k)]$ and $E[z_1(n-1,k+1)] - E[z_1(n,k)]$, for $m > n$:

$$\{E[z_1(m-1,k+1)] - E[z_1(m,k)]\} - \{E[z_1(n-1,k+1)] - E[z_1(n,k)]\} = [p(X_{m-1} - X_m) + (1-p)(Y_{k+1} - Y_k) - c_o] - [p(X_{n-1} - X_n) + (1-p)(Y_{k+1} - Y_k) - c_o] = p[(X_{m-1} - X_m) - (X_{n-1} - X_n)]. \quad (2.42)$$

The concavity of X_m and $m > n$ implies that $|X_m - X_{m-1}| < |X_n - X_{n-1}|$. This directly means that $p[X_{m-1} - X_m + X_n - X_{n-1}] > 0$, proving that the effect of such

a substitution on the expected individual performance of type 1 workers in teams with the same number of type 2 colleagues but different size is more positive for those type 1 workers in the larger group ■

2.7.8 Officers' career charts



No.

Name

Date of birth

*Post

*Date of present appointment

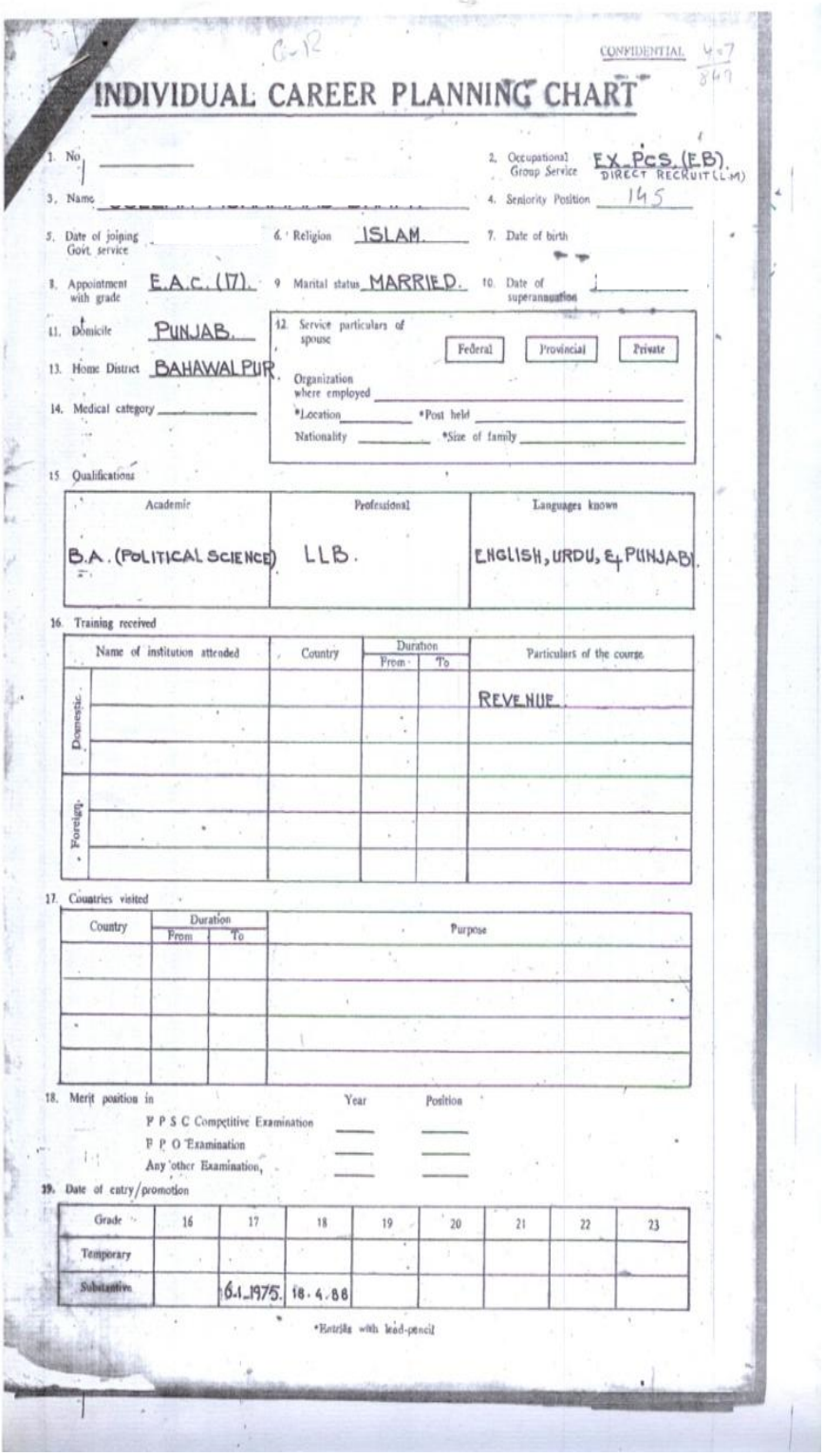
←Field
←Secretariat
←Corporation
←Soft
←Hard
←Foreign

SERVICE

Year	Year of Service	Post held	Class/ Grade	Department	Station	ACR Assessment: Reporting Officer	ACR Assessment: Countersigning Officer	Fitness for Promotion
1975	1 ST	E.A.C 10-1-75 TO 31-12-75	17	S & G.A.D	KASUR	AVG:	GOOD	PREMATURE
1976	2 nd	" 1-1-76 TO 30-6-76	"	"	"	AVG:	A/G	PREMATURE
"	"	" 1-7-76 TO 31-12-76	"	"	"	GOOD	GOOD	PREMATURE
1977	3 rd	" 1-1-77 TO 14-4-77	"	"	"	GOOD	V.GOOD	FIT
"	"	" 15-4-77 TO 31-12-77	"	"	"	GOOD	GOOD	FIT
1978	4 TH	" 1-1-78 TO 4-2-78	"	"	"	GOOD	GOOD	FIT
"	"	" 11-2-78 TO 31-12-78	"	"	LAHORE	GOOD	AVG:	IN DUE COURS
1979	5 TH	" 1979	"	"	"	V.GOOD	GOOD	FIT
1980	6 TH	" 1980	"	"	"	V.GOOD	GOOD	FIT
1981	[illegible]	" 1-1-81 TO 30-5-81	"	"	"	-	AVG	NOT YET
"	"	" 1-6-81 TO 31-12-81	"	"	WAZIRABAD	V.GOOD	-	FIT
1982	8TH	" 1-1-82 TO 27-4-82	"	"	"	V.GOOD	GOOD	FIT
		" 12-6-82 TO 31-12-82				V.GOOD	GOOD	FIT
1983	9TH	" 1-1-83 TO 31-12-83	"	"	"	V.GOOD	GOOD	FIT
1984	10TH	" 1-1-84 TO 18-6-84	"	"	"	V.GOOD	AVG:	FIT
"	"	" 20-6-84 TO 31-12-84	"	"	NANKANSAHIB	V.GOOD	GOOD	FIT
1985	11TH	" 1-1-85 TO 12-5-85	"	"	"	V.GOOD	-	FIT
"	"	" 13-5-85 TO 31-12-85	"	"	CHUNIAN	GOOD	GOOD	FIT
1986	12TH	" 1-1-86 TO 31-12-86	"	"	"	GOOD	V.GOOD	FIT
1987	13TH	" 1-1-87 TO 13-3-87	"	"		HE DID NOT WORK UNDER ANY BO		
"	"	E.A.C. 15-3-87 TO 27-4-87	"	"	CHINIOT	PERIOD LESS NO REPORT.		
"	"	M.S:30 28-4-87 TO 30-12-87	"	"	KASUR	GOOD	GOOD	FIT
1988	14TH	" 1-1-88 TO 24-10-88	18	"	"	Not	K CA	Sh[illegible]
"	"	AWAITING POSTING 29-10-88 TO 7-11-88	"	"		NO REPORT.		
"	"	S.O 7-11-88 TO 31-12-88	"	EDUCATION	LAHORE	PERIOD	LESS NO REPORT.	
1989	[illegible]	" 1-1-89 TO 3-89	"	"	"	"	"	

*Entries with lead-pencil.

Figure 2.4 – Official civil servant career chart, sheet with the postings over his professional career.



CONFIDENTIAL

INDIVIDUAL CAREER PLANNING CHART

1. No. _____
2. Occupational Group Service: EX. PCS. (E.B.) DIRECT RECRUIT (L.M)
3. Name: [redacted]
4. Seniority Position: 145
5. Date of joining Govt. service
6. Religion: ISLAM.
7. Date of birth
8. Appointment with grade: E.A.C. (17).
9. Marital status: MARRIED.
10. Date of superannuation
11. Domicile: PUNJAB.
12. Service particulars of spouse — Federal / Provincial / Private
13. Home District: BAHAWALPUR.
14. Medical category _____
Organization where employed _____
*Location _____ *Post held _____
Nationality _____ *Size of family _____

15. Qualifications

Academic	Professional	Languages known
B.A. (POLITICAL SCIENCE)	LLB.	ENGLISH, URDU, & PUNJABI.

16. Training received

	Name of institution attended	Country	Duration From	Duration To	Particulars of the course
Domestic					REVENUE.
Foreign					

17. Countries visited

Country	Duration From	Duration To	Purpose

18. Merit position in

	Year	Position
P P S C Competitive Examination		
F P O Examination		
Any other Examination,		

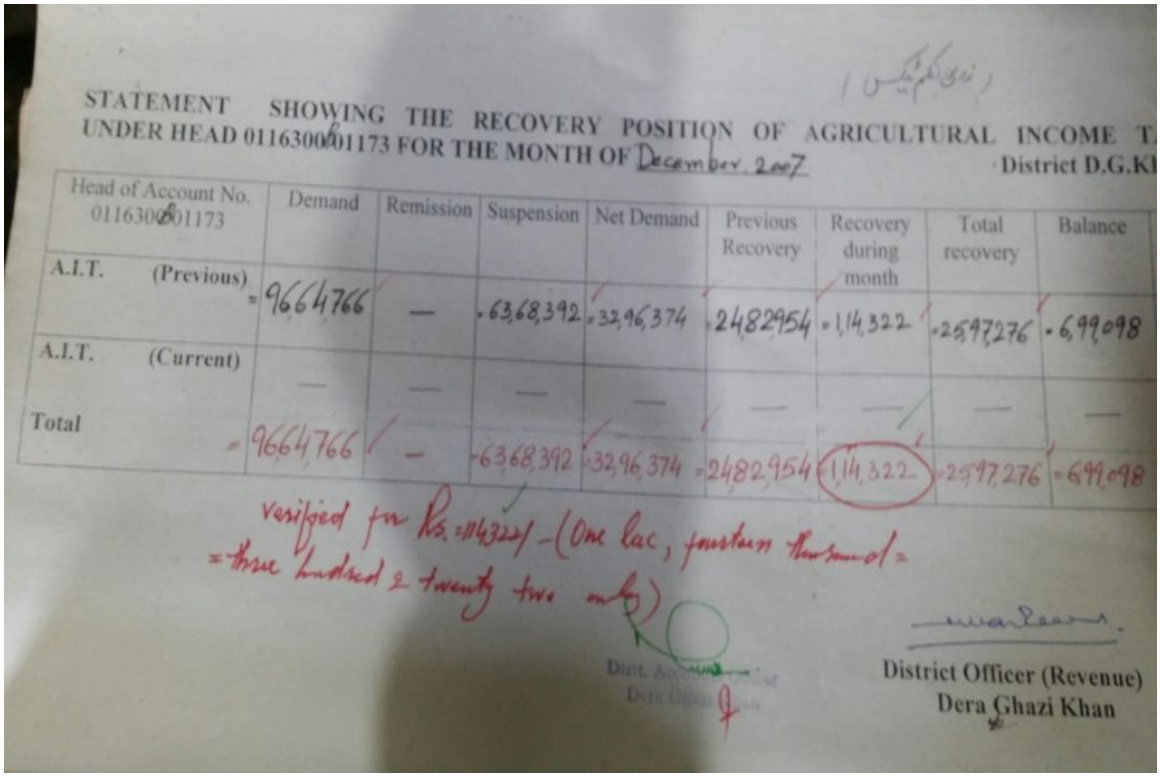
19. Date of entry/promotion

Grade	16	17	18	19	20	21	22	23
Temporary								
Substantive		6.1.1975.	18.4.88					

*Entries with lead-pencil

Figure 2.5 – Official civil servant career chart, sheet with his personal, education and professional information.

2.7.9 The tax collection form



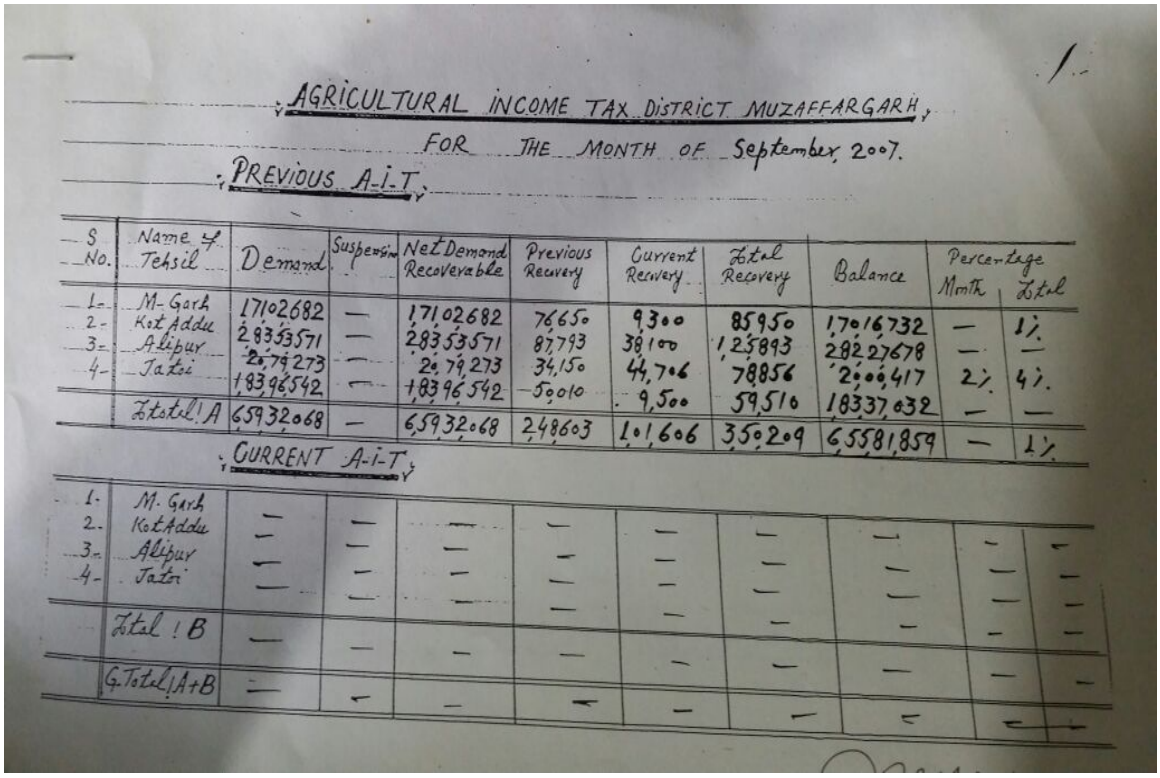
STATEMENT SHOWING THE RECOVERY POSITION OF AGRICULTURAL INCOME T
UNDER HEAD 01163001173 FOR THE MONTH OF December 2007 District D.G.K

Head of Account No. 01163001173	Demand	Remission	Suspension	Net Demand	Previous Recovery	Recovery during month	Total recovery	Balance
A.I.T. (Previous)	9664766	—	6368392	3296374	2482954	114322	2597276	699098
A.I.T. (Current)	—	—	—	—	—	—	—	—
Total	9664766	—	6368392	3296374	2482954	114322	2597276	699098

verified for Rs. 114322/- (One lac, fourteen thousand three hundred & twenty two only)

District Officer (Revenue)
Dera Ghazi Khan

Figure 2.6 – Official form for the communication of the tax collected in a given month.



AGRICULTURAL INCOME TAX DISTRICT MUZAFFARGARH,
FOR THE MONTH OF September 2007.
PREVIOUS A.I.T.

S No.	Name of Tehsil	Demand	Suspension	Net Demand Recoverable	Previous Recovery	Current Recovery	Total Recovery	Balance	Percentage Month	Percentage Total
1-	M. Garh	17102682	—	17102682	7665	9300	85950	17016732	—	1%
2-	Kot Addu	28353571	—	28353571	87793	38100	1,25893	28227678	—	—
3-	Alipur	2079273	—	2079273	34150	44706	78856	2000417	2%	4%
4-	Jatoi	1839542	—	1839542	50010	9500	59510	1833032	—	—
	Total! A	65932068	—	65932068	248603	101606	350209	65581859	—	1%

CURRENT A.I.T.

1-	M. Garh	—	—	—	—	—	—	—	—	—
2-	Kot Addu	—	—	—	—	—	—	—	—	—
3-	Alipur	—	—	—	—	—	—	—	—	—
4-	Jatoi	—	—	—	—	—	—	—	—	—
	Total ! B	—	—	—	—	—	—	—	—	—
	G.Total(A+B	—	—	—	—	—	—	—	—	—

Figure 2.7 – Official form for the registry of agricultural income tax.

2.7.10 Average annual targets and monthly performance per fiancial year

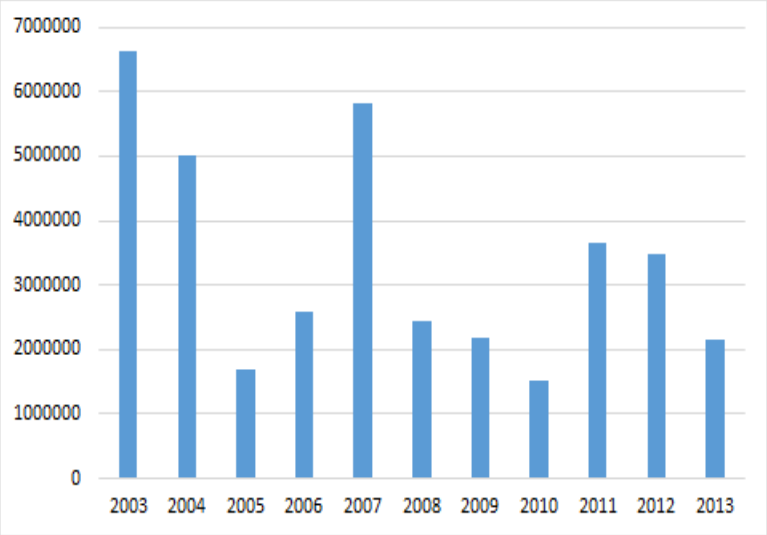


Figure 2.8 – Average target across tehsils for the corresponding financial year, in million PKR.

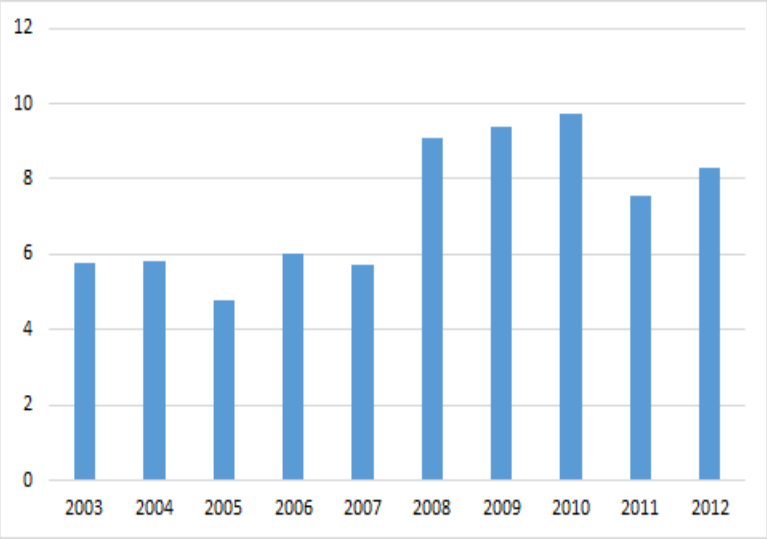


Figure 2.9 – Average monthly performance for the corresponding financial year, in percentage of the annual target.

2.7.11 Average performance per month

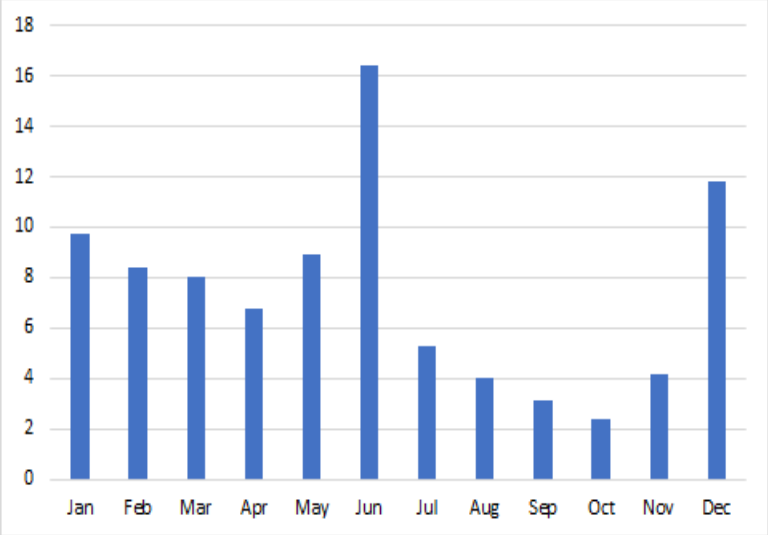


Figure 2.10 – Average performance in the different months of the year.

2.7.12 Descriptive statistics for the main variables

Variable	Obs.	Mean	Std. Dev	Min	Max
Y	7018	7.733	13.680	0	100
colleagues	7018	11.444	13.507	0	115
AC_colleagues	7108	2.350	1.648	0	10
other_colleagues	7108	8.570	12.570	0	107
mill_coll	7107	0.217	0.412	0	1
N_mil_coll	7107	0.275	0.593	0	5
DC_mil_coll	7108	0.058	0.234	0	1
AC_mil_coll	6937	0.031	0.173	0	1
other_mil_coll	7107	0.180	0.430	0	3

Table 2.7 – Simple descriptive statistics for some of the variables in the study.

2.7.13 Distribution of the number of AC colleagues

AC_colleagues	Freq.	Percent	Cum.
0	746	10.50	10.50
1	1,805	25.40	35.89
2	1,609	22.64	58.53
3	1,407	19.80	78.33
4	663	9.33	87.66
5	575	8.09	95.75
6	242	3.41	99.16
7	30	0.42	99.58
8	9	0.13	99.70
9	10	0.14	99.85
10	11	0.15	100.00
Total	7,107	100.00	

Figure 2.11 – Distribution of the variable *AC_colleagues* for the ACs in our sample.

2.7.14 The number of military colleagues for the ACs in our sample

N_mil_coll	Freq.	Percent	Cum.
0	5,566	78.32	78.32
1	1,237	17.41	95.72
2	210	2.95	98.68
3	82	1.15	99.83
4	9	0.13	99.96
5	3	0.04	100.00
Total	7,107	100.00	

Figure 2.12 – Distribution of the variable *N_mil_coll* for the ACs in our sample.

2.7.15 Distribution of the number of *other colleagues*

other_colleagues	Freq.	Percent	Cum.
0	166	2.34	2.34
1	461	6.49	8.82
2	690	9.71	18.53
3	850	11.96	30.49
4	1,035	14.56	45.05
5	779	10.96	56.02
6	555	7.81	63.82
7	391	5.50	69.33
8	285	4.01	73.34
9	217	3.05	76.39
10	163	2.29	78.68
11	269	3.79	82.47
12	184	2.59	85.06
13	170	2.39	87.45
14	167	2.35	89.80
15	100	1.41	91.21
16	51	0.72	91.92
17	65	0.91	92.84
18	19	0.27	93.11
19	26	0.37	93.47
20	5	0.07	93.54
21	1	0.01	93.56
25	6	0.08	93.64
26	5	0.07	93.71
27	10	0.14	93.85
28	7	0.10	93.95
29	8	0.11	94.06
30	1	0.01	94.08
31	12	0.17	94.25
32	20	0.28	94.53
33	30	0.42	94.95
34	12	0.17	95.12
35	14	0.20	95.31
36	20	0.28	95.60
37	26	0.37	95.96
38	16	0.23	96.19
39	15	0.21	96.40
40	6	0.08	96.48
41	8	0.11	96.59
42	6	0.08	96.68
43	9	0.13	96.81
44	33	0.46	97.27
45	15	0.21	97.48
46	10	0.14	97.62
47	9	0.13	97.75
48	9	0.13	97.88
49	3	0.04	97.92
51	6	0.08	98.00
52	9	0.13	98.13
53	5	0.07	98.20
54	3	0.04	98.24
55	5	0.07	98.31
56	10	0.14	98.45
57	5	0.07	98.52
58	9	0.13	98.65
60	3	0.04	98.69
65	11	0.15	98.85
66	5	0.07	98.92
68	15	0.21	99.13
69	4	0.06	99.18
70	5	0.07	99.25
78	4	0.06	99.31
79	4	0.06	99.37
80	4	0.06	99.42
101	7	0.10	99.52
102	7	0.10	99.62
105	7	0.10	99.72
106	14	0.20	99.92
107	6	0.08	100.00
Total	7,107	100.00	

Figure 2.13 – Distribution of the variable *other_colleagues* for the ACs in our sample.

2.7.16 Marginal effect of an extra colleague on individual performance

With the coefficient associated to the variable *colleagues* $\beta_1 = 0.18$ and the coefficient associated to the variable *colleagues_exp* $\beta_2 = -8.91 \times 10^{-7}$ in column (2), table 2.4, the marginal effect of having an extra colleague on individual performance

Y_{it} is given by

$$\frac{\partial Y_{it}}{\partial colleagues} = 0.18 - 3.5 \times 8.91 \times 10^{-7} colleagues^{2.5}.$$

The following table shows how this marginal effect for different sizes of groups, between 1 and 80.[80]

$colleagues$	1	5	15	25	50	75	80
$\frac{\partial\ Y_{ikdmt}}{\partial\ colleagues}$	0.1799	0.1798	0.1773	0.1703	0.1248	0.0281	0.0015

Table 2.8 – Marginal effect of an extra colleague on individual performance, in homogeneous groups without hierarchy being considered.

2.7.17 Average performance as a function of the number of AC colleagues

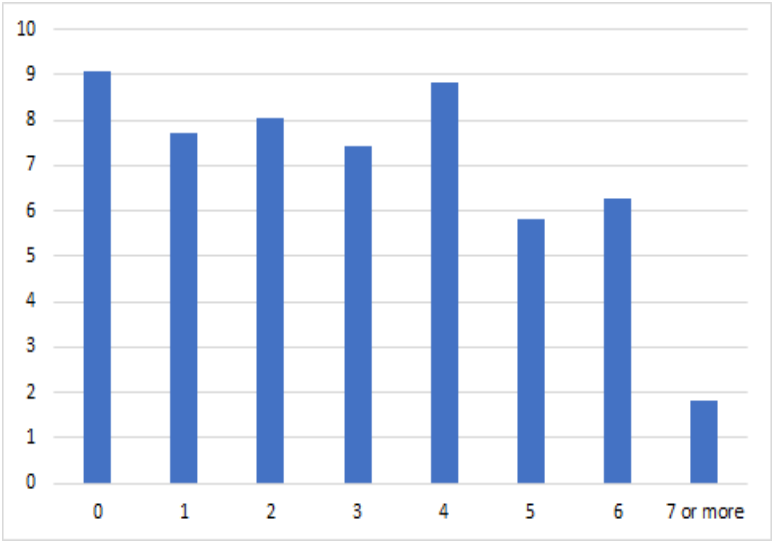


Figure 2.14 – Average performance for different numbers of AC colleagues.

[80]The 99.23% of all the districts in which civilian tax collectors are working in a given period have 80 or less workers. In concrete, out of 7106 observations, 6885 correspond to tax collectors in groups with a size lower than 80.

Chapter 3

Waving Goodbye? The Determinants of Autonomism and Secessionism in Western Europe

joint with - Martín Portos[1] and John Vourdas.[2]

This chapter sheds light on the main aggregate-level determinants of electoral support for regionalist parties across 10 Western European countries. A region being relatively richer than the country to which it belongs is associated with higher electoral support for regionalist parties only to the extent that the region is culturally differentiated. This hypothesis is substantiated theoretically, tested empirically and found to hold in the form of a strong and significant interaction effect between cultural and economic variables. This result, omitted in previous studies, implies a profound change in the interpretation of the role of income and cultural differences in explaining support for regionalism, for both autonomist and separatist parties.

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3.1 Introduction

The study of the determinants of the break-up of countries and the origin of new nation-states received considerable attention following the collapse of the Soviet Union and Yugoslavia.[3] Recently, this topic has regained momentum as two large regions have been pushing for their independence.[4] In Scotland the *Scottish National Party*-led Government held a referendum on independence from the UK in September 2014. Despite the unionist win, a sizable proportion of 44.7% of voters opted for secession (turnout: 84.59%). Likewise, Catalan authorities strove to hold an official plebiscite on independence, but faced outright opposition from the Spanish Government and the Constitutional Court. Given these circumstances, a large-scale *non-binding* unofficial voting performance led by civil society organizations took place instead, with the collaboration of the Catalan regional Government. In total, over 2.3 million votes were cast in November 2014 (estimated turnout was approximately 40%), with 80.8% of participants ticking the 'yes-yes' option (i.e. yes, for a state for Catalonia; yes, for an independent state)(Della Porta et al., 2017).

While these are arguably two extreme cases, support for greater regional[5] autonomy has been rising within EU member states, against a backdrop of the wider European integration process between member states. However, electoral research tends to overlook the relevance of the center-periphery axis on vote choice (Medeiros et al. 2015).

In line with the most recent literature, we will refer to *regionalism* as the process of agitation within a sub-state territorial unit or region that leads to increasing demands for greater autonomy, which seeks to recognize, empower, and reinforce its structure of self-government (De Winter et al. 1998; Massetti 2009). Within regionalist parties, we define a party as *autonomist* if it does not intend to secede in any way from the current state, it respects the unity of the current state, and simply has an ambition for a larger degree of regional self-government (Massetti and Schakel 2016: 5, 13; Jolly 2006). A party is *secessionist* if it promotes a territorial subunit's detachment from the nation-state of which it is currently part, and advocates for the right to self-determination, either by becoming an independent state or by building a new one together with other territorial units (Sorens 2005, 2008, 2012). Consequently, we include irredentist parties as a subcategory of secessionist parties. Hence, regionalism embeds both autonomism and secessionism, with the latter being a more radical form of regionalism and the former a milder form.

[3]Nation-states combine the state as a system of political action with national identity, the community's entitlement to claim for self-rule (Keating 2004).

[4]In the vast majority of cases, secessionism demands take the form of separatism, oriented to supplying regions with independent state structures. There are exceptions, however, as people in some regions would rather prefer to join another state. For instance, the German-speaking community in the Italian South Tyrol may prefer a reattachment to Austria instead of forming a state on their own. This phenomenon is known as *irredentism*, which is frequently considered a specific sub-type of secessionism (Sorens 2005: 308, Sorens 2008: 339-340).

[5]A *region* is a 'territorial body of public law established at the level immediately below that of the state and endowed with political self-government' (Assembly of European Regions 1996; Hooghe et al. 2010). We use *regions* and *territorial sub–units* interchangeably throughout. A *nation* is defined as a community of people with a set of coordinated beliefs about their cultural identities that claim self-government, with varying degrees of intensity (Moreno 1995: 237; Laitin 2007: 40- 41).

Despite the rise of regionalist parties and movements in the last decades (in France, Spain, Italy and the UK, amongst others), there have been surprisingly few empirical studies on the determinants of their support. Even though there are some notable exceptions to this trend (eg., Sorens, 2005, 2008, 2012; Massetti and Schakel, 2016; Brancati, 2014), we consider that two crucial issues warrant further study, as there is no consensus about them in existing literature. Firstly, what is the relation between cultural and economic factors in explaining the electoral success of different regionalist forces? Secondly, what is the connection between the two main forms of regionalism, i.e. autonomism and secessionism? Are they two different versions of the same phenomenon or two distinct phenomena?

We argue that cultural proximity accounts for the support for increasing regional autonomy through an interaction between cultural and income-related variables which has not been explored in the existing literature. The main finding is that a region being richer relative to the rest of the country is only correlated with support for more regional autonomy if its culture is significantly different from the main one in the country, and not otherwise. Similarly, the cultural–identity gap is significantly more important in accounting for the success of regionalist and secessionist parties in relatively rich regions, playing a much smaller role in poorer ones. This common feature underpins both autonomist and secessionist electoral support. Finally, the paper develops the idea that —at least in electoral studies —these two forms of regionalism are intimately intertwined, both on theoretical and empirical grounds.

The paper is structured as follows. The next section reviews the relevant contributions in the literature. The third section develops our theoretical framework. The data, empirical model and main results from the empirical enquiry are described in the fourth section. The fifth section concludes by highlighting the main implications of this paper.

3.2 Literature review

The main factors identified in the literature as accounting for regionalist support— either in its autonomist or secessionist versions— can be divided in two broad categories: cultural and economic (Brancati, 2014; Hooghe et al., 2010; Jolly, 2006; Massetti and Schakel, 2016; Sorens, 2005, 2008, 2012).

Cultural explanations of support for greater regional autonomy emphasize the role of historical, traditional, linguistic and ethnic factors. These are often associated with some distinctive identity features, such as having a specific minority language (Van Houten, 2000; Fearon and Van Houten, 2002).[6] For example, cultural explanations help to explain the support for secessionism in Catalonia and the Basque Country. These two regions have a strong tradition of identity nationalism linked to their language, and in both regions secessionist parties gathered approximately 60%

[6] *National identity* is the sense of a nation as a cohesive whole. It refers to the set of tendencies and values derived from the feeling of belonging to a united group of people with distinctive traditions, history and culture. National identity is neither fixed nor alterable at will. It requires a periodical redefinition in the light of historical features, present needs and future aspirations Parekh 1995 remarks.

of the votes in the last regional elections.[7] However, Catalan is also spoken in the regions of Valencia and the Balearic Islands, which are both autonomous communities that have traditionally shown active hostility to secessionism, although there has been some, rather mild, support for autonomism (Riera, 2014).[8] Similarly, while Scottish separatism has been on the rise in the last decades, Scottish Gaelic is barely spoken by 1% of Scots. This contrasts with the situation in Wales, where around 20% of the population speaks Welsh, but support for secessionism is much lower. Having a distinctive minority language might not be the only (or even the main) sign of cultural difference. Other cultural or identity aspects might play a role in determining support for greater regional autonomy. In fact, Desmet et al. 2011 show that physical distance between the capitals of two countries is a better proxy for cultural difference than the linguistic distance between their main languages. Yet, cultural factors alone cannot explain support for greater regional autonomy. We argue that cases of culturally differentiated, but relatively poor, regions, such as Galicia in Spain, Sicily in Italy or the French overseas departments, where the support for regionalism is relatively low or non-existent, show that cultural-identity factors alone cannot explain a large support for autonomist or secessionist parties.

It is well known that economic variables such as income, wealth and relative economic well-being may also influence secessionist and autonomist support. Appeals to primordial past, history and traditions of a nation seem to affect voting to a much lesser extent than material concerns and socio-economic issues, at least when it comes to endorsing secessionist parties (Sorens, 2005). Accordingly, debates on territorial separation (and also current prosecessionist referendum campaigns, such as the recent Scottish and Catalan ones) have often focused on the economic efficiency losses and gains of separation vis-à-vis the status quo.[9] From an individual level of analysis, political economists have addressed this issue as well. The established literature on the break-up of nation-states, for instance, offers a trade-off that determines whether or not secession is optimal for a given individual (e.g., Alesina and Spolaore, 1997). While integration facilitates coordination and minimizes the duplication of fixed costs in the provision of public goods (e.g., in defence and law enforcement), the main incentive for independence is that the benefits from remaining united are generally not evenly distributed among all citizens (nor regions) at the country level. For instance, heterogeneity in tax contributions across regions, resulting from differences in average income per capita, accentuate economic grievances (Bolton and Roland, 1997). The latter are at the core of claims for greater autonomy and secession: the argument is that the centre's economic policies are holding the growth of the region down or that the (richer) region is subsidizing poorer ones (Horowitz, 1981). The Italian Lega Nord political party often puts these arguments forward, for example. There seems to be a widespread agreement in the literature that richer regions tend to be more prone to back autonomist (De Winter et al., 1998; Van Houten, 2000; Gordin, 2001) and secessionist parties (Sorens, 2005).

Some existing contributions have already considered the interrelated effect of both

[7] Considering the following parties as secessionists: CiU, ERC, ICV, CUP and SI in Catalonia; and PNV and Bildu in the Basque Country (Nordsieck, 2015) (see table 3.7 in appendix 3.6.2).

[8] The Basque language is also spoken in Navarre, where there is indeed a relatively high support for both autonomist and secessionist parties.

[9] Muñoz and Tormos 2015 emphasize the importance of economic aspirations and partisanship in their inquiry on individual-level determinants for secessionism in Catalonia.

cultural and economic variables to explain secessionist support. For example, in their study on the trade-offs between the benefits of large jurisdictions and the costs of heterogeneity of large and diverse populations, Alesina and Spolaore 1997 present a model that implies that democratization leads to secessions, there is an inefficiently high number of countries in equilibrium, and the equilibrium number of countries increases in the amount of economic integration. In his study of ethnic conflict in Eurasia, Hale 2008 finds an association between ethnic distinctiveness and separatism that he contends is because ethnicity accentuates difficulties of union governments at portraying themselves as non-exploiters of minority groups on the benefit of the dominant group. Focusing on Yugoslavia, Desmet et al. 2011 find that agents' preferences over different geographical configurations (i.e. the likelihood of secessions and unions) is determined by trade-off between the costs of greater cultural heterogeneity and increasing returns in the provision of public goods.

Whilst these contributions are enlightening and advance theories to an, arguably limited, extent consistent with our main argument (i.e., economy and culture interact to promote greater support for autonomism and secessionism), this is, to the best of our knowledge, the first empirical paper with aggregated panel data that focuses on unravelling the crucial interaction effect between cultural and economic variables in explaining the support for autonomist and secessionist parties. This points not only towards an inadequacy of additive models to test for the determinants of regionalist support, but also a potential lack of theorization on the interplay between economic and cultural arguments as explanatory factors.

Another important question refers to the connection between autonomism and secessionism. It is widely accepted that these two processes are interrelated in conceptual and empirical terms (e.g. Jolly, 2006). They share many crucial aspects, as both reject and react against the status quo in favour of some alternative involving more self-government. However, some studies have stressed their diverging features (Sorens, 2008). From this point of view, autonomism and separatism would be different processes, driven by different dynamics and factors. Existing empirical evidence suggests that cultural variables are most important in determining autonomist support (Gordin, 2001; Fearon and Van Houten, 2002), whereas economic variables are most important in determining secessionist support (Sorens, 2005; Brancati, 2014). We argue that both cultural and economic factors and, most importantly, their interaction drive the electoral support for both autonomist and secessionist parties in the same direction. This, together with other empirical findings, suggests that, at least in electoral studies, autonomism and secessionism should be considered as two varieties of the same process, namely regionalism.

3.3 Theoretical framework

3.3.1 Cultural proximity, relative income, and electoral support for regionalism

Cultural proximity influences the feeling of belonging to a large social group and determines whom people in a given region region care about. This has an important

role in the political participation process. When choosing whether or not to support greater regional autonomy, people whose region's culture is distinct from the majority of the nation will care more about the implications of that decision for the population in that same territorial subunit. On the other extreme, in regions whose culture mainly coincides with the main one in the country, people will tend to care relatively more about the effects that a certain political choice would have for the overall population in the country as a whole. In this context, this gap between the regional and the majoritarian culture in the country is known as *cultural distance*.

This effect of culture on electoral support for regional autonomy has important implications, as it introduces an important interaction between economic and cultural factors. With people in more differentiated regions caring mainly about the well-being of those in their same region, support for regionalism among the population will be large if this is thought to improve the situation of the full group, provided that the region is rich. Alternatively, the population in a relatively rich region will support regionalism to a large degree only when the region's culture is significantly different from the predominant one in the country. Those in highly differentiated but poor regions will tend to see the less decentralized status quo as better for their region's material interests, and we would expect a relatively low proportion of the electorate to support increasing regionalism. This analysis brings us to the main hypothesis of the paper:

Hypothesis 1: There exists a positive interaction effect between cultural and economic factors on the support for increasing regional autonomy.

This interaction between economic and cultural aspects underpinning the vote for regionalist parties has been overlooked in the literature to date, as existing aggregate studies are based on additive models. This interaction has important implications, both to explain the support for regionalist parties and to contribute to a better understanding of the determinants of the relationship between the electoral support for secessionist and for autonomist options.

3.3.2 Cultural proximity, autonomism and secessionism

The interrelationship between secessionism and autonomism warrants further analysis. From a theoretical point of view, we approach this puzzle using a simple model that builds on Sorens 2004 contribution. Voters are located on a continuum ranging from 0 to 6, with 0 representing maximum unionism and 6 representing independence. We assume that the election is regional (and not a referendum), and we care about any voter i, not necessarily the median voter. Let us assume, for simplicity, that there are only two parties in the election, a centralist one and a regionalist one, with proposed policies respectively being P_c and P_r. Voter i preferences are given by the negative loss function:

$$U(P_j, I_i) = -a(|P_j - I_i|)^2, \tag{3.1}$$

where a is a positive constant, $U(P_j, I_i)$ is the utility of voter i under policy P_j and I_i is the ideal policy point of voter i. In our example, the policy offered by the

centralist party is $P_c = 1$, and voter i preferred policy point $I_i = 4$. If the regionalist party is either an autonomist party with $P_r = 3$, or a secessionist party with $P_r = 6$, voter i will choose to vote for the regionalist party (one of the two existing in this region). This is consistent with the fact that not necessarily all the people who vote for secessionist parties in a regional election want their region to break away from their current nation-state. Similarly, in regions without secessionist parties, a part of the electorate of autonomists parties might want the region to secede. This misalignment between the preferred level of regional autonomy and voting behaviour derives from the existence of a discrete number of parties, and raises the following question: should the determinants of autonomism and secessionism through electoral results be studied as two different processes or as two aspects of the same phenomena?

We argue that analyzing electoral support for these two options as different processes might lead to misleading conclusions. If secessionist parties are included in the group of 'non-autonomist parties' when empirically analyzing the determinants of electoral support for autonomist parties, the results might be biased (see Figure 3.2 in appendix 3.6.3 in the supplemental data online). As a given predictor might have an effect not only on autonomism but also on the support for secessionist parties, considering only autonomist parties as an independent category biases the estimated effect of this variable downwards. Alternatively, if support for autonomist parties is put together with non-regionalists when studying support for secessionist parties, the estimate will be biased.

In order to test this, we split the full sample into two separate ones. The first of these keeps only those regions and periods that have only votes for secessionist and nonregionalist parties, or for non-regionalist parties alone. The second contains those observations in which there is a positive proportion of votes either for autonomist and non-regionalist parties, or for just non-regionalist parties. The observations for those regions that have a positive amount of votes for the two different categories of regionalist parties are excluded in both samples, i.e., regions with support for autonomist parties are excluded from the first sample and observations with support for secessionist parties are dropped in the second one. Given that we argue the same mechanism underlies electoral support for autonomist and secessionist parties, we would expect the following hypotheses to hold:

Hypothesis 2a: For the models explaining electoral support for either autonomist or secessionist parties, the coefficients for the same variables across models (with full and the separated samples) should show statistically different results.

Hypothesis 2b: When only the separated samples are considered, coefficients explaining support for autonomism and secessionism should not differ in statistical terms.

If hypotheses 2a/2b are satisfied, placing secessionism and autonomism in the same continuum measuring different degrees of regionalism will be justified, with maximal unionism and secessionism located at the extremes, and autonomism in between. As both increasing regional autonomy and secessionism imply steering policies to be more regional specific, we would expect the effect of the interaction between economic and cultural variables to go in the same direction —albeit not necessarily with the same intensity —for the two forms of regionalism. This gives the third

hypothesis of the paper:

Hypothesis 3: The interaction effect between cultural and economic variables is positive in models explaining the electoral support for both autonomism and secessionism separately.

Confirming this hypothesis (with the separated samples) is consistent with the view of secessionism and autonomism as two forms of minority nationalism.

3.4 Empirics

3.4.1 Data

We built a cross-sectional data set using data from regions of Portugal, Spain, France, the UK, Italy, Germany, Belgium, the Netherlands, Denmark and Austria (NUTS-1 regions for Germany, Belgium, Denmark and the UK; NUTS-2 for the other cases; see table 3.6, in appendix 3.6.2).

We then merged it with the 1969–2000 data set from Sorens 2005, updating this with the most recent elections—till 2014—, and adding some explanatory variables and regions.[10] Our analysis was restricted to West European countries for two reasons. Firstly, they all have established and comparable regional elections. Secondly, while cultural differences are highly correlated with geographical distances across Western Europe (Desmet et al., 2011), this is arguably not the case in countries that were settlement colonies in the past. By reducing the sample to Western Europe, we can confidently use geographical distance as a proxy for cultural differences.

The dependent variables are respectively given by the percentage of votes for autonomist (v_auton), secessionist (v_sec), and the sum of both types of parties (v_reg) in a given regional election.[11] As the centre–periphery territorial cleavage tends to be channelled through the institutional domain in well-established democracies, these are used as proxies for general support for each of these political options.

To determine under which category a given party falls, we use different secondary and primary sources (manifestos, party websites and various academic contributions). Our party classification fits Nordsieck 2015 recent categorization for that respective election (see 3.7, appendix 3.6.2).[12] For instance, the autonomist Partido Regionalista de Cantabria is in favour of greater regional autonomy for Cantabria

[10] We exclude Dutch, British and French overseas countries and territories (and also the Channels Islands and Isle of Man). The same holds for Greenland (Denmark), given its quasi-independent status. In turn, we include outermost regions (Azores, Madeira, Canary Islands, French overseas departments). We also consider the following 'special cases': Ceuta and Melilla (Spain), Gibraltar (UK) and Faroe Islands (Denmark).

[11] Our data for the percentage of votes casted for a party come both from Nordsieck 2015 *Parties and Elections* database and official regional or state-level resources. When more than one party fits in the secessionist or autonomist category, we aggregate their percentages. To be included, the party must have gained either seats in the regional chamber or more than 1% of votes.

[12] Following Massetti and Schakel 2016 criteria, in electoral coalitions where regionalist parties are involved, seat allocation is used to assign vote shares to the coalition partners.

but not independence from Spain, whereas the Scottish SNP is characterized as secessionist because it campaigns on a platform seeking independence from the UK.[13]

Our two main groups of explanatory factors, cultural proximity and economic aspects, are operationalized through different predictors, as follows.

Cultural variables

- *Language* is the proportion of residents in the region who speak a language other than the predominant one in the country. Having a regional vernacular language strengthens the regional cultural identity.[14] Aiming at protecting it, citizens may be keener to vote for regionalist parties (data sources: Lewis and Gary 2013; Sorens 2005).[15]
- *Distance* is the straight-line physical distance between the capitals of the region and the country, measured in hundreds of kilometres. In Western Europe, physical distance has historically been an obstacle to ensuring political coordination, cultural homogenization and reinforcing a sense of belonging. As Desmet et al. 2011 show using World Value Survey (WVS) data, the correlation between cultural distance and geographic distance is high (0.52) between West European countries.[16] As a proxy for cultural distance, we expect *distance* to be positively correlated with a region's desire for greater regionalism —and the effect should be larger for relatively rich regions.

A concern is whether *distance* might affect *v_reg* significantly through alternative channels, other than cultural. As abovementioned, using geographical distance as a proxy for cultural distance would be problematic for the whole world, particularly for former settlement colonies (e.g., United States, Canada, Australia). We test for the effect of *distance* on *v_reg* in these three large former colonies. The coefficient for this variable and the interaction *distance_GDP* (where GDP refers to gross domestic product ratio) are not significant in any of the regressions, pointing towards alternative channels through which geographic distance could affect electoral support for regionalist parties not being particularly relevant.[17] As an alternative test, we run a two-stage least squares (2SLS) model to explain *v_reg*, instrumenting distance and its interaction *distance_GDP* with *language* and its interaction *language_GDP*.

[13] In some cases, it can be challenging to classify political parties. For example, it is not clear to which extent the Bavarian CSU, Northern Irish UUP and Navarra's UPN act separately from statewide parties (Massetti and Schakel, 2016). We rely on Nordsieck 2015 and Sorens 2005 criteria, and considered the party as regionalist or not depending on the election. Excluding these problematic cases does not change our findings.

[14] This refers to long-term established regional languages, excluding recent linguistic minorities (e.g., first generations of migrants).

[15] Estimating the proportion of speakers and defining the linguistic status (i.e. whether it is a dialect or a language) is often problematic. Although *language* is time-invariant, it should be a good proxy for cultural heterogeneity.

[16] The correlation holds if the analysis by Desmet et al. 2011 is restricted to the countries in our sample (0.44). It is always higher than the correlation between linguistic and cultural distance: 0.42 in their sample, 0.33 for ours.

[17] We run a pooled ordinary least squares (OLS) regression with Sorens 2005 panel sub-sample for these three countries (N=1,000). As expected, while *distance* and the other related variables are never significant, *language* is still significant.

Both variables are positive and statistically significant (see table 3.11, appendix 3.6.2).[18]

Economic variables

- *GDP_ratio* measures the relative difference in the average income between the region and the whole country (regional GDPpc/ national GDPpc). We centre this variable around 1, such that it takes the value 0 when the GDP per capita of the region and that of the country are equal, and positive (negative) if the GDP per capita of the region is larger (smaller) than that of the nation as a whole.[19] We expect a positive effect for this variable through its interaction with cultural distance (with positive coefficients for the interactions *distance_GDP* and *language_GDP*): richer regions will support greater autonomy and secession to avoid redistribution to poorer regions when cultural distance is larger.

- *Richer_neighbor* is a dummy that captures whether the region has a border with another country that is richer than the country to which it belongs, as this is associated with positive economic expectations toward independence or greater autonomy.

We also include different control variables in our models, as follows.

Main controls:

- As support for greater regional autonomy might have increased over time, *year* captures the year when the election took place.

- *Has_neighbor* is a dummy (taking the value 1 if the region has a border with another country and 0 otherwise) to isolate the effect of richer_neighbor from the general effect of having a neighbor.

- *Population*: The number of the region's inhabitants, in hundreds of thousands. The impact of having a larger population on the desire for greater autonomy and secession is ambiguous. More populated regions tend to have more weight on countrywide political decisions, which should decrease the support for increasing regional autonomy. However, large populated regions are more viable as independent states, which should increase the support for secessionism.

- *Chamber_size* measures the number of seats in the regional parliament, and is positively associated with multipartism.

- *Regional_elect* is a dummy that distinguishes the nature of the election in Sorens 2005 data (1= regional; 0= national election). We expect voters to support regional parties more strongly in regional elections.

[18] The hypothesis of weak instrument is rejected (in model 4, F-test for excluded instruments is F(2,120)=6.23, p=0.0027, for *distance*, and 4.08, p=0.0194, for *distance_GDP*).

[19] Given that no observation in our sample gets close to a 0 value for *GDP_ratio*, centering this variable around 1 is more appropriate (the lowest value in our sample is 0.4; observations below 0.6 are rare).

Variable	N	Mean	Std. Deviation	Min	Max
GDP_ratio	1232	-0.041	0.222	-0.597	1.197
distance	1309	3.240	5.159	0	93.755
language	1309	0.142	0.241	0	1
distance_GDP	1232	-0.279	2.263	-40.144	15.739
language_GDP	1232	-0.009	0.082	-0.408	0.443
year	1309	1990.937	9.243	1969	2014
has_neighbor	1309	0.503	0.500	0	1
neighbor_richer	1309	0.254	0.435	0	1
population	1269	25.555	39.533	0.298	492.71
regional_elect	1309	0.415	0.493	0	1
chamber_size	1179	67.256	39.489	2	237
*ENERP**	1073	3.673	1.400	0.529	10.721
hist_together*	1173	0.559	0.490	0	1
region_auton*	1309	2.183	1.239	0	4
irredentist_potential*	1309	0.112	0.315	0	1
party_elsewhere*	1309	0.133	0.339	0	1

Table 3.1 – *Descriptive statistics. The variables with * are only used in robustness checks.*

- *Country FEs* (fixed effects) are country dummies that capture specific (institutional, historical, cultural) characteristics of each country that might be correlated with support for regional parties.

Besides these variables (see table 3.1 for descriptive statistics; for the correlation between the main predictors, see table 3.8, appendix 3.6.2), additional controls are used for robustness checks. We control for the level of regional autonomy (*regional_auton*), irredentist potential (*irredentist_potential*), whether the region is part of a EU member state (*EU*), it has past historical records of independence (*hist_together*; *indep*) and is the capital of the country (*Capital*), religious differences (*religion*), squared physical distance (*distance_sq*), the degree of multipartism (*ENERP*), and if some of its regional parties also contest elections in other regions (*party_elsewhere*) —for a description of these variables, see appendix 3.6.1.

Although all these variables have been tested, some are excluded from the reported models for various reasons, such as having important endogeneity problems (e.g. the degree of autonomy already obtained by the region and *ENERP*) or not being significant in several of the specifications. The latter includes some variables described above, such as *distance_sq*, *EU*, *religion*, *indep*, and *capital*, as well as other minor controls such as the legal status of the language (whether or not it is official), whether or not the region is in the mainland, population density and ideological gap, measured as the absolute difference in votes for left-wing parties in the territorial subunits for their respective last regional and general elections.

3.4.2 The empirical model

The estimation methodology used is a pooled ordinary lest squares (OLS) regression with country fixed effects and errors clustered at the regional level.[20] This equation gives the main model specification:

$$Votes_{jkt} = \alpha_k + \beta GDP\_ratio_{jt} + \delta distance_j + \rho language_j + \lambda(distance \times GDP\_ratio)_{jt} + \gamma(GDP\_ratio \times language)_{jt} + \sum_{j=1}^{H} \theta_h X_{jt} + \epsilon_{jt}. \tag{3.2}$$

The percentage of votes for regionalist parties in region j, country k and period t, is modelled as a function of GDP_ratio, $distance$, $language$, the interactions $distance\_GDP$, $language\_GDP$, and other controls X. As some model specifications include country dummies, there is a potential dependence of constant α $_k$ on the country k, i.e.,

$$\alpha_k = \alpha + \sum_{k=1}^{K-1} \omega_k 1_{1 \in k}$$

where $1_{1 \in k} = 1$ if region i belongs to country k and 0 otherwise.

Although v_reg is the main dependent variable, electoral support for the two subtypes of regionalist parties, autonomists (v_auton) and secessionists (v_sec) are also used as dependent variables in some model specifications.

The main hypotheses from the theoretical framework are tested empirically in the following manner:

- Hypothesis 1: we expect that (at least one of) the coefficients for $distance\_GDP$ and $language\_GDP$ will be positive and significant. Formally:

$$H_o = \lambda > 0, \gamma > 0. \tag{3.3}$$

- Hypothesis 2a: a Wald test comparing the coefficients of the models for v_sec using the full and separated samples should report statistical differences. The same holds for v_auton.
- Hypothesis 2b: In the models for v_auton and v_sec using separated samples, the main coefficients should not be statistically different.
- Hypothesis 3: hypothesis 1 should hold also when explaining support for autonomist and secessionist parties separately. As we argue using the full sample would yield biased coefficients, we use the separated samples. At least either λ or γ should be significant in the corresponding regressions.

[20] The earliest election in our data set is in 1969, the last in 2014. Data in this full interval of time are not available for all regions and elections. Even though historical and institutional differences between the countries might be important, given that the effect of country-level factors on the support for regionalism is not the focus of our study, we include country fixed effects.

3.4.3 Results

Table 3.2, with the pooled OLS analysis of the determinants of v_reg (large sample, errors clustered by region) gives the main results of the paper. The richest specification, including country fixed effects, is our preferred model (Column 4). Overall, the solid empirical evidence provided —supported by numerous robustness checks —confirms our four hypotheses. We analyze our results for each hypothesis next.

Hypothesis 1

The interaction terms $distance\_GDP$ and $language\_GDP$ have a positive effect on v_reg at the 1% level (table 3.2). When the interactions are introduced into the model, the GDP_ratio is no longer significant. This means that relative regional per capita income accounts for regional party support through its interaction with cultural variables, and not by itself. Without the interaction terms, this coefficient is significant (columns 1 and 3, table 3.2) because of omitted variables bias. This interaction, which has been overlooked to date in empirical studies, is crucial for interpreting the main factors behind the support for regionalist parties.

To illustrate this, we analyze the marginal effects of this interaction in our preferred model (column 4, table 3.2). If a region is 100 km farther away from the capital of the country than another region, *ceterisparibus*, the expected difference in the percentage of votes cast for regionalist parties depends on GDP_ratio as given by:

$$\frac{dv\_reg}{ddistance} = 1.53 + 2.18 GDP\_ratio. \tag{3.4}$$

Similarly, conditional upon the value of GDP_ratio, the effect of a marginal change in the proportion of speakers of a regional distinctive language on v_reg is given by:

$$\frac{dv\_reg}{dlanguage} = 20.44 + 43.66 GDP\_ratio. \tag{3.5}$$

Table 3.3 top shows the marginal effects of distance for different values of GDP_ratio. From the first row, we can see that a region located 600 km away from the capital is, *ceterisparibus*, more likely to show a greater support for regional parties than one which is 500 km away. However, this effect is conditional on the relative economic affluence of the region. If the two hypothetical regions we are comparing are relatively poor, with the GDP per capita in the region being only half of that of the country (GDP_ratio= –0.5), being 100 km farther away implies an increase of 0.44% in votes casted for regionalist parties. If these two regions were very rich, with the GDP per capita of both regions being 80% larger than the national GDP per capita (GDP_ratio=0.8), being 100 kilometers farther away would imply a 3.28% increase in regionalist support. Similarly, if a region's per capita GDP equals the national average (GDP_ratio= 0), there will be a 20.44% increase in votes for regionalist parties if everybody speaks a vernacular language relative to not having a regional language. If these two same regions are very rich in relative terms

	(1) v_reg	(2) v_reg	(3) v_reg	(4) v_reg
GDP_ratio	19.82***	0.291	13.90***	-3.288
	(6.044)	(5.181)	(4.093)	(4.630)
distance	0.767***	1.695***	0.683***	1.528***
	(0.252)	(0.320)	(0.215)	(0.305)
language	23.09***	28.16***	17.03***	20.44***
	(7.464)	(5.950)	(6.181)	(5.915)
distance_GDP		2.636***		2.184***
		(0.736)		(0.676)
language_GDP		52.71***		43.66***
		(17.46)		(15.51)
year			0.152***	0.158***
			(0.0412)	(0.0387)
has_neighbor			-2.763	-4.894*
			(2.932)	(2.691)
richer_neighbor			12.63***	11.54***
			(3.339)	(3.235)
population			-0.162***	-0.165***
			(0.0582)	(0.0511)
chamber_size			0.0849*	0.113***
			(0.0493)	(0.0419)
regional_elect			2.681***	2.453***
			(0.677)	(0.697)
Country FEs	No	No	Yes	Yes
Observations	1232	1232	1102	1102
R^2	0.317	0.420	0.531	0.587
Adjusted R^2	0.316	0.417	0.523	0.579

Table 3.2 – *Pooled ordinary least squares (OLS) model explaining votes for regionalist (autonomist + seccesionist) parties using the full sample. The constant term is excluded from the table for paucity reasons. Errors clustered at the regional level. Standard errors are given in parentheses. *p<0.10, **<0.05, ***p<0.01.*

(GDP_ratio= 0.8), regionalist electoral support will increase by 55.37%. However, if these regions are very poor (GDP_ratio = -0.5), the marginal effect of language on v_reg becomes negative. Hence, the model predicts that very poor and culturally differentiated regions will tend to be more centralist than equally poor regions which are more culturally similar to the rest of the country.[21]

GDP_ratio	-0.5	0	0.5	0.8
$\frac{\partial\ v\_reg}{\partial\ distance}$	0.44	1.53	2.62	3.28
$\frac{\partial\ v\_reg}{\partial\ language}$	-1.39	20.44	42.27	55.37

	language			
$\frac{\partial\ v\_reg}{\partial\ GDP\_ratio}$	0	0.25	0.5	1
0	0	10.91	21.83	43.66
100	2.18	13.09	24.01	45.84
km 500	10.92	21.83	32.75	54.58
1000	21.84	32.75	43.67	65.50
2000	43.68	54.59	65.51	87.34

Table 3.3 – *Top: Marginal effect of increasing distance by 100 km and language from 0 to 1 on support for regionalist parties for different values of GDP_ratio. Bottom: Marginal effect of GDP_ratio on support for regionalist parties for different values of distance and language.*

The implications of the interaction term for the marginal effect of differences in GDP per capita between the region and the country are— even more— critical. Since the coefficient for GDP_ratio is not significant for any of our models with interactions, the marginal effect of a one-unit change in GDP_ratio on v_reg, is fully dependent on the value taken by the cultural variables, being 0 for a region whose culture is identified as the main culture in the country.[22] Formally:

[21] Beyond the scope of this paper, this finding presents an interesting avenue for inquiry for the social psychological literature on national identity (e.g. Bloom, 1993; Spinner-Halev and Theiss-Morse, 2003).

[22] We explored the implications of the region having the capital of the country in an unreported regression with a dummy. Its coefficient is not statistically significant once geographical distance is controlled for, and does not alter the results.

$$\frac{dv\_reg}{dGDP\_ratio} = 2.18distance + 43.66language. \tag{3.6}$$

3.3-bottom shows how the effect of GDP_ratio on regionalist vote depends on the distance at which the given region is from the capital of the country, and the proportion of speakers of a regional distinctive language. In two regions with no vernacular language, which are 100 km away from the capital and whose GDP_ratio differs by one unit, the predicted difference of regionalist support is only 2.18%. This difference becomes much higher (43.68%) for a 2000 km distance. The effect of the interaction with *language* is also very large: for two regions that have 25% of speakers of a vernacular language, the difference in expected support for regionalist parties would be 13.09% (if located at 100 km from the capital) and 54.59% (at 2000 km from the capital). With a 100% of vernacular language speakers in these regions, differences would become 45.84% and 87.34%, respectively.[23]

To sum up, from these analyses, we conclude that the following:

1. The degree to which cultural differences between a region and the majoritarian culture in its country affect the support for regionalism in Western Europe is significantly influenced by relative regional affluence. Being more culturally differentiated is associated with a large gain in support for regionalism in relatively rich regions, but with a much smaller one for relatively poor ones.
2. Being relatively richer only increases support for regionalism in regions whose culture is significantly different from the predominant one in the country.

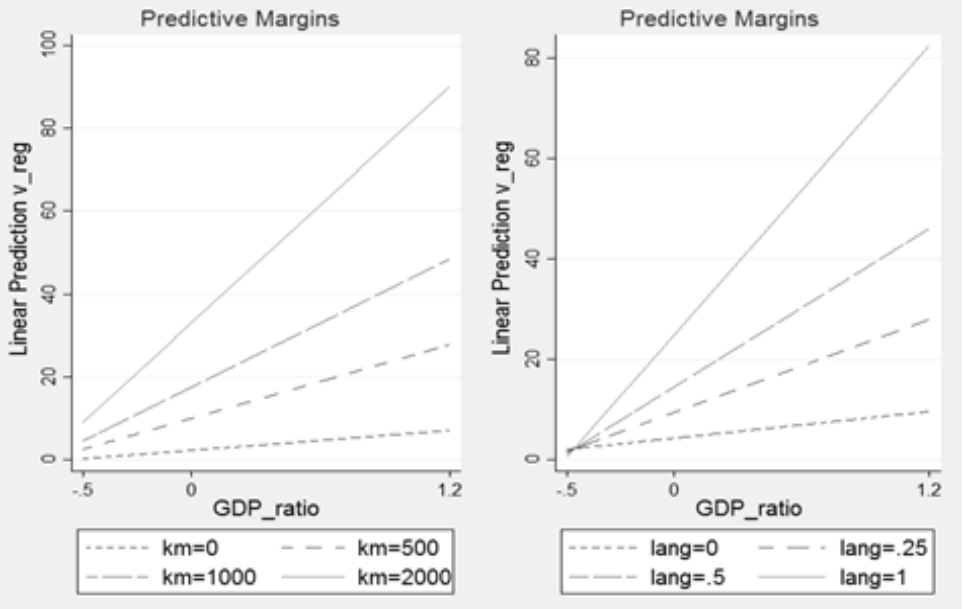

Figure 3.1 – LHS: Predicted vote for regional parties (v_reg) as a function of GDP_ratio for given values of distance (in 100 km). RHS: Predicted vote for regional parties (v_reg) as a function of GDP_ratio for given values of *language* (in proportion 0-1). The other variables are evaluated at their average values.

[23]This is an extreme case, but in fact more than 90% of the population speaks a vernacular language in some sub-units, such as the German-Speaking Communities in Belgium or the Faroe Islands in Denmark.

Figure 1 illustrates the relevance of the interaction term for the model predictions. An increase in *GDP_ratio* translates into different predictions of votes for regionalist parties depending on the distance at which the corresponding region is from the capital of the country. While regionalist parties in a relatively rich region with a *GDP_ratio* of 0.8 and located 500 km away from the capital of the country are expected to obtain around 20% of the votes, this share is almost 60% in a region located at 2000 km from the capital, keeping the other variables at their means. Equivalently, the effect of differences in *distance* on the share of votes for regionalist parties is much smaller for poor regions. When we compare two equivalent regions with a *GDP_ratio* of -0.5 but at 500 and 2000 km from the capital, we see that the difference in the percentage of predicted votes is less than 10%. For the same difference in *distance*, the predicted share of votes for regionalist parties in two rich regions with a *GDP_ratio* of 0.8 differs by almost 40%.

Similarly, for a relatively rich region (*GDP_ratio*= 0.8), voting intention for regionalist parties fluctuates between 15%, 25% and 47%, as the percentage of speakers of the regional distinctive language changes from 25%, to 50% and 100%, *ceterisparibus*. In a relatively poor region (*GDP_ratio*= -0.5), the predicted support for regionalists is almost 0. In this case, having different proportions of speakers of a minority language does not affect regionalist voting.

We conducted several tests to check whether our findings are robust to different methodologies and specifications. Including only one of the two cultural variables and its interaction with *GDP_ratio* is enough to cancel out the latter's effect and obtain a positive and significant interaction (table 3.9, appendix 3.6.2). Results hold if we use only the last regional election for every case (N= 120; table 3.10, appendix 3.6.2), and if we run tobit models (table 3.12, appendix 3.6.2) which are left- and right-censored at 0 and 100 respectively to reflect the fact that the dependent variable, by definition, can never fall outside these bounds. The interaction between cultural and economic factors is also robust to instrument *distance* and *distance_GDP* with *language* and *language_GDP* in a 2SLS regression.[24] This model should capture the exogenous effect of cultural distance and its interaction with *GDP_ratio* (table 3.11, appendix 3.6.2). Finally, the interactions are also robust to running a model with frequency weights, in which each region gets a weight proportional to its population (table 3.13, appendix 3.6.2).

Returning to the main model (regression 4, table 3.2), our controls report some significant effects. A 1 million increase in a region's population is associated with a decrease of a 1.65% in the expected percentage of votes for regionalist parties. This result is very robust across different specifications,[25] and also for the models with either *v_sec* or *v_auton* as dependent variables— with the separated sample.[26]

[24] In this specification, the coefficient for *distance_GDP* is larger than in the main model. The effect of *GDP_ratio* on *v_reg* becoming negative and significant for the 2SLS regression means that the population in not-culturally differentiated regions which are richer would vote less for regionalist parties than the population in poorer ones, taking the main thesis of the paper to the extreme.

[25] The negative significant coefficient for *population* holds also in non-reported robustness checks, such as including the contry's population, or the relative population of the region over the population of the country as regressors, or taking the log of the variable instead of the level.

[26] *Population* loses its significance and changes its sign only in the regressions with the full sample and *v_sec* as the dependent variable (table 3.15, appendix 3.6.2). Note we contend throughout

Models compared	# Diff.	Different coefficients
v_auton sep - v_sec sep	0	-
v_sec full - v_auton full	0	-
v_auton full - v_auton sep	3	year, language_GDP, language.
v_sec full - v_sec sep	2	richer_neighbor, population.

Table 3.4 – *The number of different coefficients between the models. Wald test, 10% level of significance. Full stands for the full sample, sep for the separated sample, which excludes the regions with a positive amount of the other type of regionalist vote.*

Thus, having a larger weight on nationwide politics seems to ease regionalist aspirations. Coefficients associated to the variables *year*, *regional_elect*, *chamber_size*, and *richer_neighbor* are positive, as expected, while having a neighboring country which is poorer than the current one (*has_neighbor*=1 and *richer_neighbor*=0) decreases regionalist support— at the 10% level of significance. Including country fixed effects improves the explanatory capacity of the model, and does not have much impact on the size of coefficients.

Hypotheses 2

We proceed next to analyze whether *v_sec* and *v_reg* should be kept aggregated in *v_reg* or should be better analyzed independently. We run a Wald test to test whether each coefficient is equal across the two models being compared. Table 3.4 reports the number of statistically different coefficients in each model comparison.[27]

The third row shows that the Wald test rejects the hypothesis of equal coefficients for three variables: there are three coefficients which are different between the model explaining *v_auton* using the full sample, i.e. including those regions with some *v_sec*, and the model explaining *v_auton* using the separated sample, only with regions without secessionist votes. When *v_sec* becomes the dependent variable two statistically different coefficients are reported for the same models with different samples (row 4). Hence, hypothesis 2a holds: for the models using *v_sec* and *v_auton* as the dependent variables, the regression coefficients corresponding to the same variables across two different samples show statistically significant different results.

While the evidence provided so far is coherent with the argumentation for the coeffi-

that these models are biased.

[27]The explanatory variables included in each of these models are the same as those included in the main model (Column 4, table 3.2). The models in the table are respectively: *v_sec sep* (Column 2, 3.5); *v_auton sep* (Column 4, table 3.5); *v_sec full* (Column 2, table 3.15, appendix 3.6.2); and *v_auton full* (Column 4, table 3.15, appendix 3.6.2).

cients in one of the models to be biased, it does not indicate which of the two options —full or separated sample —is better. Two pieces of evidence offer some guidance in this choice. The first —arguably limited—argument concerns explanatory capacity. The two models with the separated samples have a higher explanatory capacity than with the full samples (R^2 is 0.52 vs 0.35 for *v_sec*— columns 2, table 3.5 and table 3.15, appendix 3.6.2— and 0.62 vs 0.45 for *v_auton*— columns 4, table 3.5 and table 3.15, appendix 3.6.2—).

The second piece of evidence is given by the result of testing hypothesis 2b. It has been argued that if both *v_sec* and *v_auton* are explained by similar factors, the coefficients of a model studying these two phenomena together using a joint sample, would be biased. Hypothesis 2b helps us in answering this question as it gives as a quantifiable measure of how different are the coefficients between the models explaining *v_sec* and *v_auton*. A Wald test does not reject the null hypothesis of the coefficients being equal for any of the variables —not even at the 10% level. This holds both for the models using the separated and full samples (rows 1 and 2, table 3.4). Hence, hypothesis 2b is also satisfied, as there are no statistically different results between the coefficients in the models explaining the support for autonomist and secessionist parties.

In short, all available evidence supports aggregating the two sub-types of regionalist voting together. However, given that they have been frequently studied separately in the existing literature, it seems relevant to assess whether the main results for the determinants of *v_reg*, and specifically the interaction between cultural and economic factors, hold for each form of regionalism.

Hypothesis 3

Since this paper points towards an important bias in the results for *v_sec* and *v_auton* using the full sample, we will test whether the interactions between cultural and economic variables are significant with separated samples. In order to shed light on the determinants of *v_sec*, we drop the observations with a positive value for *v_auton* (N= 759), and conversely we drop the positive observations for *v_auton* when studying *v_sec* (N= 822) (3.5).

Although *distance_GDP* loses its significance,[28] the interaction *language_GDP* keeps it, thus confirming hypothesis 3. Also, the effect of *GDP_ratio* vanishes as we bring in the interactions. These findings are robust to using Tobit instead of OLS, including frequency weights, using only the last cross-section of the data, running a 2SLS model (instrumenting distance and its interaction with language and its interaction), and including only one of the cultural variables and its interaction. Some minor exceptions aside,[29] hypothesis 3 is satisfied and the interaction effect between cultural and economic variables is positive and significant in models explaining secessionism and autonomism.

[28] The *p*-value for *distance_GDP* is 0.105 though —Column 4, table 3.5.

[29] There are two exceptions. With *v_sec* as the dependent variable, if only *distance* and its interaction are included as cultural variables, neither *GDP_ratio* nor the *GDP_distance* interaction are significant, and if we use only the last cross section, the interactions are not significant (N= 75).

	(1) v_sec	(2) v_sec	(3) v_auton	(4) v_auton
GDP_ratio	5.584*	-0.720	9.046**	-6.875*
	(3.023)	(5.099)	(4.267)	(3.601)
distance	0.619	0.638	0.438***	1.025***
	(0.471)	(0.481)	(0.162)	(0.294)
language	5.266*	12.89**	5.905	16.01***
	(3.024)	(5.018)	(4.133)	(4.469)
distance_GDP		0.135		1.128
		(1.434)		(0.690)
language_GDP		40.33***		63.66***
		(13.83)		(13.76)
year	0.102***	0.103***	0.0957***	0.111***
	(0.0287)	(0.0277)	(0.0316)	(0.0320)
has_neighbor	0.664	-1.060	1.102	-2.003
	(1.338)	(1.396)	(1.368)	(1.235)
richer_neighbor	5.842**	5.653**	5.791**	5.104***
	(2.685)	(2.663)	(2.430)	(1.839)
population	-0.115**	-0.118**	-0.157**	-0.130***
	(0.0497)	(0.0468)	(0.0610)	(0.0433)
chamber_size	0.0804**	0.0906**	0.0778*	0.0900***
	(0.0404)	(0.0378)	(0.0395)	(0.0343)
regional_elect	1.279	1.254	1.226***	1.084***
	(0.793)	(0.777)	(0.384)	(0.366)
Country FEs	Yes	Yes	Yes	Yes
Observations	759	759	822	822
R^2	0.492	0.519	0.459	0.619
Adjusted R^2	0.480	0.506	0.447	0.609

Table 3.5 – *Vote for secessionist and autonomist parties. Pooled ordinary least squares (OLS) model explaining votes for secessionist (columns 1 and 2) and autonomist parties (columns 3 and 4). The regression for each type of regionalist vote excludes those regions with a positive amount of the other type of regionalist vote (separate samples). Errors are clustered at the regional level. The constant term is excluded for paucity. Standard errors are given in parentheses. *p<0.10, **<0.05, ***p<0.01.*

Despite potential concerns regarding research design (i.e. the samples have been artificially separated), as the results for secessionist and autonomist support are consistent and comparable to those for *v_reg*, the interdependency of cultural and economic explanatory factors is reinforced.

Exploring other variables and related robustness checks

This section briefly explores the additional controls used, on top of those reported in the tables. Some of these controls are excluded because they were not significant in the main regression, or not robust to different specifications, and do not modify any result significantly.[30] The other reason to exclude some of the controls was their endogeneity problem, namely *regional_auton* and *ENERP*. These two variables have played a preeminent role in the literature so far (e.g. Sorens, 2005; Massetti, 2009), but suffer from an important problem of simultaneity, as they are directly affected by the dependent variable. To tackle this problem, we have instrumented them with more exogenous variables.

ENERP is instrumented through *chamber_size*, a crucial aspect in the magnitude of district (Taagepera and Shugart, 1989), and a 2SLS regression is run. We find a 2SLS positive and significant coefficient for *ENERP* —*F*-statistic test for weak instruments= 9.10 (p= 0.0031)—, implying that a higher degree of multipartism is associated with a better electoral performance of regionalist parties (Column 1, table 3.14, appendix 3.6.2). Similarly, we instrument *regional_auton* with *hist_together*. While the *F*-statistic of excluded instruments for the first stage is a bit low (2.65, p= 0.106), the 2SLS coefficient for *region_auton* is 29.17, and significant at the 1% (see column 2, table 3.14, appendix 3.6.2). This points towards higher regional autonomy having a positive effect on regionalist support.

There are two additional caveats to our results: (1) the main model does not take into account irredentist particularities, and (2) some parties are present in several regions at the same time, which might make these observations non-independent.

When we incorporate *irredentist_potential* into our model, it does not have an impact on regionalist voting and does not change our findings (Column 4, 3.2). Additionally, when we drop the 18 territorial units where this variable was positive, our main results still hold (see column 3, table 3.14, appendix 3.6.2). To control for potential problems derived from the same regionalist parties contesting elections in different regions, we include the *party_elsewhere* variable. Again, when we include this variable in the regression it is not significant and does not affect the results. These are also robust to dropping the observations corresponding to the 17 regions with relevant regional parties contending in some other region (e.g. Lega Nord, PNV, etc.) (see column 4, table 3.14, appendix 3.6.2).

[30] These include *distance_sq*, *EU*, *religion*, *indep*, and *capital*, as well as the legal status of the language (whether or not if it is official), whether or not the region is in the mainland, population density, the population of the country, the proportional population of the region over that of the country, and the ideological gap.

3.5 Conclusions

This paper analyzes the effect of cultural and economic factors on voters' desire for greater regional autonomy and independence using a panel of territorial subunits in 10 West European democracies. We extended the traditional theory using the concept of cultural proximity. The main argument is that the population of richer regions is more likely to tolerate transfers to poorer regions as long as they feel part of the same national group. In relatively rich and culturally differentiated regions, there should be a larger political support for regionalism. This hypothesis is tested empirically using a data set with the results from regional elections in these countries between 1969 and 2000 —updated with the most recent elections till 2014. Evidence in support of the predictions of the theoretical framework is found in the form of statistically significant interaction effects between cultural and economic variables.

Moreover, regional relative affluence only has a positive effect on the support for regionalism through these interaction terms: a region being relatively richer is only associated with an expected higher support for regionalist parties to the extent that it is culturally differentiated (i.e., the proportion of minority language speakers and physical distance are larger). Equivalently, the degree to which a region's cultural difference is associated with a higher support for regionalist parties depends on its relative income, as this effect is much larger for rich than for poor regions. Also, both theory and empirical evidence suggest that support for autonomist and secessionist parties should be considered together in electoral studies: the interaction between income and culture underpins both, and there are good reasons to think that models using common samples to study these two phenomena separately will be biased.

Further research is necessary to unravel plausible interaction effects between income and cultural variables beyond Western Europe, and also to understand why the interactions do not hold for some particular cases. Additional theoretical and empirical studies that incorporate microdata should complement this study by analyzing whether this interaction effect applies at an individual voter level – and, in that case, exploring the concrete mechanism that might explain it. Also, locating all (regionalist and nonregionalist parties) that compete in an election on a territorial continuum that ranges from extreme secessionism to maximum unionism (e.g., on the basis of party manifestos per each election) might help us to understand further how this interaction operates.

To summarize, the main theses of the paper are supported by our empirical analyses. Firstly, cultural and economic factors affect regionalist voting through a positive and significant interaction —this even makes the relative affluence of the region insignificant on its own. Secondly, keeping aggregated autonomist and secessionist electoral support in a unique regionalist category —instead of considering them as two separated phenomena —seems more adequate. Finally, the significant interaction between income and culture in the separate explanation of autonomist and secessionist support reinforces its relevance in any electoral study of minority nationalism.

3.6 Appendix

3.6.1 Description of main unreported controls

- *Regional_auton*: The level of autonomy already obtained by the region at the time of the corresponding election, taking values 0 (less autonomous) to 4 most autonomous. If included as a control, the coefficient associated to this variable is positive and highly significant. This variable, borrowed from Sorens 2005, suffers from a serious endogeneity problem produced by simultaneity, as regions with a higher electoral support for regionalist parties tend to obtain higher quotas of autonomy. We instrument this variable with *hist_together*.
- *Hist_together* is used as instrument for *regional_auton*. As regions relatively recently annexed to their current country will tend to show a higher support for regionalist parties, we create a dummy variable which takes the value 1 if the region has always been part of the country since 1648, and 0 otherwise. The year 1648, when the Treaty of Westphalia was signed, marks the "end of the feudal system of family properties and the beginning of modern state nationalism" (Sorens 2005: 309). Having been part of the union since then might be associated with lower support for regionalism.
- *Indep* is a dummy variable similar to *Hist_together*—*but less restrictive*—and borrowed from Sorens 2005. It takes value 1 if the region has declared itself an independent country or served as the capital province of an independent country different from the current state at any point since 1648.
- *ENERP*: Effective Number of Electoral Regional Parties. As regionalist parties are often small, highly disproportional systems that reduce party choices are supposedly detrimental to them. The formula by Laakso and Taagepera 1979 (Sorens, 2005) is adapted:

$$ENERP = \frac{1}{\sum_{i=1}^{n} p_i^2}$$

  where n is the number of parties and p_i^2 is the square of each party's proportion of all votes. Note that if a higher $ENERP$ is the consequence of larger support for regionalist parties, as one could expect, there is a problem of endogeneity. Hence, we instrument $ENERP$ trough *chamber_size* in some robustness checks.
- *Religion* is a dummy coded as 1 if at least 10% of the regional population's creed differs from the majoritarian one in the country.
- *Distance_sq* is the squared *distance*, frequently included in gravity models. As the effect of distance is expected to decrease as distance becomes larger, this variable should have a negative coefficient.
- A dummy to control whether the *capital* of the country is in the region.
- A dummy to control whether the region is part of a *EU* member state.

- In order to control for spatial autocorrelation, a dummy variable *party_elsewhere* is created. It takes value 1 if there is a regionalist party in the region which is also present and gains relevant support in another region, and 0 otherwise.
- Following Sorens 2005, we take into account the specific subtype of separatism, irredentism, that might bias our findings. A dummy variable *irredentist_potential* equals 1 if a region has a neighboring country which main language is the same as the regional language, and 0 otherwise.

3.6.2 Tables

Country	Regions
France	Alsace, Aquitaine, Auvergne, Brittany, Burgundy, Centre, Champagne-Ardenne, Corsica, Franche-Comte, Guadeloupe, Guiana, Ile-de-France, La Reunion, Languedoc-Roussillon, Limousin, Lorraine, Lower Normandy, Martinique, Midi-Pyrenees, Nord-Pas-de-Calais, Pays de la Loire, Picardy, Poitou-Charentes, Provence-Alpes-Cote d'Azur, Rhone-Alpes, Upper Normandy
Germany	Baden-Wurttemberg, Bavaria, Berlin, Brandenburg, Bremen, Hamburg, Hesse, Mecklenburg-Vor, Lower Saxony, North Rhine-Westphalia, Rhineland-Palatinate, Saarland, Saxony, Saxony-Anhalt, Schleswig-Holstein, Thuringia
Italy	Abruzzo, AostaValley, Apulia, Basilicata, Calabria, Campania, Emilia-Romagna, Friuli-VG, Lazio, Liguria, Lombardia, Marche, Molise, Piedmont, Sardinia, Sicily, Tuscany, Umbria, Veneto, Trentino-South Tyrol
Portugal	Azores, Madeira
Spain	Andalusia, Aragon, Asturias, Balearic Islands, Basque Country, Canary Islands, Cantabria, Castile La Mancha, Castile and Leon, Catalonia, Extremadura, Galicia, La Rioja, Madrid, Murcia, Navarre, Valencia, Ceuta,Melilla
U.K. Austria	Scotland, Wales, Northern Ireland, Gibraltar Burgenland, Carinthia, Lower Austria, Salzburg, Styria, Tyrol, Upper Austria, Vienna, Vorarlberg
Denmark	Hovedstaden, Midtjylland, Nordjylland, Sjælland, Syddanmark, Faroe Islands
The Netherlands	Groningen, Friesland, Drenthe, Overijssel, Gelderland, Flevoland, Utrecht, Noord-Holland, Zuid-Holland, Zeeland, Noord-Brabant, Limburg
Belgium	Flanders, Wallonia, Brussels, German-speaking communities

Table 3.6 – List of Regions included in the analysis

Country	Region	Secessionist parties	V. sec (%)	Autonomist parties	V. aut (%)
It	Emilia-Romagna, Friuli-VG, Liguria, Lombardia, Marche, Piedmont, Tuscany, Umbria, Veneto	Lega Nord	13.7, 8.3, 10.2, 13, 6.3, 16.7, 6.5, 4.3, 35.5		
It	Sardinia	PdS, iRS, ProgReS	6.2	RM, PSd'Az, RS, UDS	17.5
It	Sicily			PdS, GS, PC	21.4
It	Trentino	LN	6.2	UPT, PATT, PT, CT, AT	45.7
It	South Tyrol	STF, F, BU	27.2	SVP, VGV, TA, AAC	59
It	Molise			GS	5.1
UK	Gibraltar			GSD, LP, GSLP	100
UK	Scotland	SNP, SGP	48.4		
UK	Northern Ireland	SF	30	SDLP	12.2
UK	Wales	PC	17.9		
Be	Flanders	N-VA, VB	37.8		
Be	Brussels	N-VA, VB	2.7	FDF	13.1
Be	Germ-speak comm.			ProDG	22.2
Au	Tyrol	STF, LN-Alto Adige,	9.7	SVP, CU-Lad	47.8
Au	Burgerland			LBL	4
Neth	Groningen			Partij voor het Noorden	3.15
Neth	Friesland			FNP, P. voor het Noorden	9.5
Neth	Utrecht			PLP Utrecht, Mooi Utrecht	0.55
Neth	Noord-Holland			ONH	1.88
Neth	Zeeland			Partij voor Zeeland	5.66
Denm	Faroe Islands	FF, T, F	47.1	SSF, MF	10.4
Po	Azores			PDA	0.49
Ger	Bavaria	BP	2.1	DF	0.74
Ger	Schleswig-Holstein			SSW	4.6
Sp	Andalusia			PA	2.5
Sp	Aragon			PAR, CHA	18
Sp	Asturias			FAC	25.2
Sp	Balearic Islands	EQUERRA	1.3	PSM, IB-LLIGA, CxI, ENE, Ume	12.7
Sp	Basque Country	PNV, EHB/-Bildu, A, EA	59.6		
Sp	Canary Islands			CC, Nca	35
Sp	Cantabria			PRC	29.8
Sp	Castile and Leon			UPL	1.9
Sp	Catalonia	CDC, ERC, CUP	39.9	UDC, ICV	15.6
Sp	Galicia	BNG	10.2	ANOVA, CxG	15
Sp	La Rioja			PR	5.6
Sp	Navarre	PNV, EHB/-Bildu, A, NaBai	29.4	UPN, CDN	36.8
Sp	Valencia			COM	7.4
Sp	Ceuta			CAB	14.5
Sp	Melilla			CM, PPL	30.9
Fr	Alsace			Alsace d'Abord	25.9
Fr	Aquitaine	PNV, AB	0.7		
Fr	Brittany	BP	4.3	Terres de Bretagne	2.6
Fr	Corsica	CL	9.4	PNC	18.4
Fr	La Reunion	NR	0.9	PCR	30.2
Fr	Martinique	PPM, RDM, BPM	51	MIM	32.2
Fr	Pays de la Loire	BP	1		
Fr	Provence-Alpes-Cote d'Azur			LS	2.7

Table 3.7 – Classification of regionalist political parties and votes—in the last regional election considered till 2014—in percentage.

	v_reg	v_sec	v_aut	GDP_rat.	dist.	lang.	dist_GDP
v_reg	1						
v_sec	0.768	1					
v_auton	0.7757	0.1927	1				
GDP_ratio	0.2445	0.1770	0.2005	1			
distance	0.3197	0.1592	0.3334	-0.1155	1		
language	0.4207	0.2909	0.3584	-0.0575	0.2182	1	
dist_GDP	-0.0300	0.0239	-0.0697	0.3670	-0.8078	-0.1418	1
lang_GDP	0.1497	0.0791	0.1516	0.6602	-0.2040	-0.4007	0.4082

Table 3.8 – Correlations between the main variables related to regionalist support, income and cultural differences.

	(1) v_reg	(2) v_reg	(3) v_reg	(4) v_reg
GDP_ratio	10.05***	0.707	14.02***	2.332
	(3.787)	(5.023)	(4.255)	(4.582)
distance	0.898***	2.035***		
	(0.260)	(0.463)		
distance_GDP		3.205***		
		(0.955)		
language			22.08***	28.78***
			(7.079)	(7.411)
language_GDP				49.47***
				(16.03)
year	0.149***	0.158***	0.193***	0.196***
	(0.0437)	(0.0416)	(0.0442)	(0.0434)
has_neighbor	-2.838	-3.513	-2.808	-4.693
	(3.220)	(3.005)	(3.152)	(3.114)
richer_neighbor	14.06***	12.65***	12.49***	12.14***
	(3.875)	(3.642)	(3.405)	(3.347)
population	-0.217***	-0.234***	-0.141**	-0.122**
	(0.0629)	(0.0593)	(0.0615)	(0.0557)
chamber_size	0.133**	0.157***	0.0605	0.0649
	(0.0535)	(0.0505)	(0.0526)	(0.0471)
regional_elect	2.773***	2.691***	2.883***	2.689***
	(0.690)	(0.691)	(0.681)	(0.698)
Country FEs	Yes	Yes	Yes	Yes
Observations	1102	1102	1102	1102
R^2	0.481	0.534	0.484	0.511
Adjusted R^2	0.473	0.526	0.476	0.502

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.9 – Vote for regionalist parties, using only one cultural variable and its interaction with *GDP_ratio*. Pooled OLS model explaining votes for regionalist (autonomist + secessionist) parties using the full sample. The constant term is excluded from the table for paucity. Errors clustered at the regional level. Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

	(1) v_reg	(2) v_reg	(3) v_reg	(4) v_reg
GDP_ratio	30.15***	-3.179	22.41***	-4.782
	(10.43)	(7.356)	(5.776)	(7.534)
distance	0.353**	1.094***	0.461**	1.117**
	(0.172)	(0.372)	(0.182)	(0.499)
language	31.00***	38.68***	20.33***	25.31***
	(6.564)	(7.562)	(6.958)	(8.568)
distance_GDP		1.439		1.210
		(0.974)		(1.127)
language_GDP		103.1***		76.68***
		(30.12)		(28.84)
year			-1.637	-0.916
			(1.417)	(1.389)
has_neighbor			0.469	-3.784
			(2.900)	(2.734)
richer_neighbor			12.89***	13.31***
			(4.073)	(3.866)
population			-0.166*	-0.199**
			(0.0856)	(0.0903)
chamber_size			0.0435	0.130
			(0.0732)	(0.0803)
Country FEs	No	No	Yes	Yes
Observations	120	120	120	120
R^2	0.370	0.535	0.645	0.711
Adjusted R^2	0.354	0.514	0.586	0.656

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.10 – Vote for regionalist parties. Cross sectional OLS model explaining votes for regionalist (autonomist + secessionist) parties using the reduced sample, which only includes observations compiled by the authors. The constant term is excluded from the regression tables for paucity. Errors clustered at the regional level. Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

	(1) v_reg	(2) v_reg	(3) v_reg	(4) v_reg
GDP_ratio	33.03***	-16.91	13.47***	-21.06**
	(8.567)	(19.61)	(4.179)	(9.724)
distance	5.817***	9.812***	2.986***	5.559***
	(1.911)	(3.302)	(0.943)	(1.402)
distance_GDP		16.53*		11.08***
		(8.576)		(3.793)
year			0.0127	0.135**
			(0.0701)	(0.0668)
has_neighbor			-2.613	-5.095
			(2.973)	(3.216)
richer_neighbor			13.08***	8.817*
			(3.661)	(5.140)
population			-0.232***	-0.279***
			(0.0632)	(0.0779)
chamber_size			0.167***	0.228***
			(0.0541)	(0.0703)
regional_elect			1.997***	2.220***
			(0.714)	(0.733)
Country FEs	No	No	Yes	Yes
Observations	1232	1232	1102	1102

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.11 – Vote for regionalist parties. 2SLS model explaining votes for regionalist (autonomist + secessionist) parties using the full sample. Distance is instrumented with language and *distance_GDP* with *language_GDP*. The constant term is excluded from the table for paucity. Errors clustered at the regional level. Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

	(1) v_reg	(2) v_reg	(3) v_reg	(4) v_reg
GDP_ratio	36.81***	-0.895	21.75***	-2.457
	(11.11)	(13.64)	(5.393)	(8.565)
distance	1.321***	3.244***	0.932***	2.141***
	(0.443)	(0.676)	(0.282)	(0.471)
language	48.78***	52.95***	32.43***	32.94***
	(12.42)	(10.46)	(9.599)	(8.459)
distance_GDP		5.431***		3.157***
		(1.533)		(1.098)
language_GDP		76.71**		41.81*
		(30.04)		(23.64)
year			0.332***	0.351***
			(0.0822)	(0.0784)
has_neighbor			-1.209	-3.391
			(4.738)	(4.101)
richer_neighbor			18.18***	16.83***
			(5.256)	(5.044)
population			-0.213**	-0.223***
			(0.0898)	(0.0820)
chamber_size			0.122*	0.149**
			(0.0707)	(0.0627)
regional_election			6.811***	6.398***
			(1.249)	(1.314)
Country FEs	No	No	Yes	Yes
Observations	1232	1232	1102	1102

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.12 – Vote for regionalist parties. Tobit model – left censored at 0 and right censored at 100- explaining votes for regionalist (autonomist + secessionist) parties using the full sample. The constant term is excluded from the table for paucity. Errors clustered at the regional level. Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

	(1) v_reg	(2) v_reg	(3) v_reg	(4) v_reg
GDP_ratio	16.43**	-1.313	12.27***	-2.280
	(6.815)	(2.770)	(3.444)	(5.208)
distance	0.805**	0.787**	0.718***	1.025***
	(0.310)	(0.330)	(0.217)	(0.273)
language	19.77***	32.48***	9.998**	19.94***
	(7.268)	(7.013)	(4.490)	(6.104)
distance_GDP		0.670		1.457*
		(0.893)		(0.763)
language_GDP		95.18***		60.72***
		(22.47)		(18.01)
year			0.173***	0.181***
			(0.0489)	(0.0456)
has_neighbor			-0.0945	-2.943
			(1.907)	(1.913)
richer_neighbor			9.870***	7.579***
			(3.193)	(2.660)
population			-0.118**	-0.122***
			(0.0516)	(0.0459)
chamber_size			0.0634	0.0916**
			(0.0470)	(0.0419)
regional_elect			1.711**	1.683**
			(0.656)	(0.647)
Country FEs	No	No	Yes	Yes
Observations	31732	31732	28859	28859
R^2	0.262	0.458	0.573	0.635
Adjusted R^2	0.262	0.458	0.573	0.634

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.13 – Vote for regionalist parties. Pooled OLS model with frequency weights as given by -the regional- population, explaining votes for regionalist (autonomist + secessionist) parties using the full sample. The constant term is excluded from the table for paucity. Errors clustered at the regional level. Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

	(1) v_reg	(2) v_reg	(3) v_reg	(4) v_reg
regional_auton		29.17***		
		(5.690)		
ENERP	12.47**			
	(5.562)			
GDP_ratio	-6.688	-0.520	-1.012	-6.505*
	(6.009)	(5.048)	(4.624)	(3.642)
distance	1.527***	1.006***	1.139***	1.634***
	(0.434)	(0.294)	(0.292)	(0.263)
language	17.26**	11.43**	15.55**	23.69***
	(7.522)	(4.690)	(6.181)	(6.836)
distance_GDP	1.875**	0.969	1.471**	2.321***
	(0.936)	(0.662)	(0.717)	(0.601)
language_GDP	30.95	43.61***	27.88	59.34***
	(24.61)	(14.96)	(20.51)	(13.97)
year	0.683***	-0.249**	0.0857*	0.118***
	(0.248)	(0.105)	(0.0463)	(0.0389)
has_neighbor	-2.440	-2.175	-2.396	-4.995
	(3.013)	(1.561)	(1.706)	(3.256)
richer_neighbor	11.20***	9.898***	10.55***	8.317***
	(3.047)	(2.705)	(3.379)	(3.020)
population	-0.0307	-0.197***	-0.127**	-0.109***
	(0.0256)	(0.0522)	(0.0492)	(0.0413)
regional_elect	6.572***	-0.996	2.244***	1.846***
	(1.794)	(0.952)	(0.744)	(0.497)
chamber_size		0.121***	0.0828*	0.0871**
		(0.0419)	(0.0452)	(0.0375)
Country FEs	Yes	Yes	Yes	Yes
Observations	934	1096	956	939
R^2	-	-	0.612	0.636
Adjusted R^2	-	-	0.604	0.628

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.14 – Various robustness checks. 2SLS regression instrumenting $ENERP$ with *chamber_size* (1). 2SLS instrumenting *regional_auton* with *hist_together* (2). Pooled OLS excluding those regions with irredentist potential from the sample (3). Pooled OLS excluding those regions with a regional party which is also in another region from the sample (4). Errors are clustered at the regional level. The constant term is excluded from the table for paucity. Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

	(1) v_sec	(2) v_sec	(3) v_auton	(4) v_auton
GDP_ratio	4.780*	0.0519	8.967**	-4.191
	(2.534)	(4.454)	(4.097)	(4.101)
distance	0.134	0.324	0.550***	1.231***
	(0.0947)	(0.275)	(0.144)	(0.231)
language	9.314**	10.57**	7.844*	10.03*
	(3.897)	(5.289)	(4.265)	(5.561)
distance_GDP		0.481		1.760***
		(0.600)		(0.649)
language_GDP		13.59		31.05
		(17.27)		(21.37)
year	0.0958***	0.0976***	0.0583*	0.0611**
	(0.0303)	(0.0305)	(0.0307)	(0.0287)
has_neighbor	-3.143*	-3.765**	0.405	-1.049
	(1.674)	(1.742)	(1.920)	(1.641)
richer_neighbor	9.108***	8.834***	3.721	2.845
	(3.239)	(3.292)	(2.377)	(2.268)
population	-0.0396	-0.0389	-0.123*	-0.127**
	(0.0466)	(0.0450)	(0.0656)	(0.0559)
chamber_size	0.0518	0.0586	0.0303	0.0491
	(0.0413)	(0.0394)	(0.0399)	(0.0355)
regional_elect	0.952**	0.886**	1.791***	1.611***
	(0.443)	(0.438)	(0.533)	(0.534)
Country FEs	Yes	Yes	Yes	Yes
Observations	1098	1098	1072	1072
R^2	0.342	0.352	0.378	0.453
Adjusted R^2	0.331	0.340	0.368	0.442

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.15 – Vote for secessionist and autonomist parties. Standard errors in parentheses. Pooled OLS model explaining votes for secessionist parties, using the full sample, columns (1), (2), and for autonomist parties, columns (3), (4). Errors are clustered at the regional level. The constant term is excluded from the table for paucity. Standard errors in parentheses. $*p < 0.10$, $**p < 0.05$, $***p < 0.01$.

3.6.3 Figure

Figure 3.2 – Net wealth distribution in surveyed EMU countries (ECB,2013)

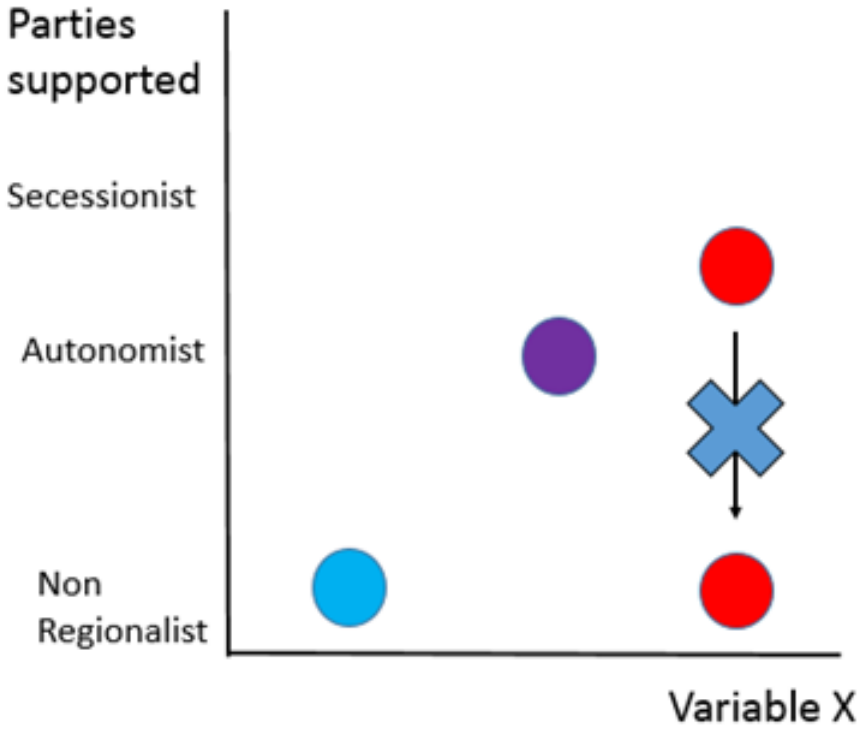

Figure 3.3 – Hypothetical support for different parties as a function of a variable X. The crossed arrow illustrates what we would be comparing —and should not compare—if we use the vote for autonomist parties as dependent variable.

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