DYNAMICAL INTERACTION BETWEEN LANGUAGES: CASTILIAN AND BASQUE A SYSTEM DYNAMICS MODEL

Gil I., Aguinagalde M.I., Graña M., Dolado J., Torrealdea F. J.
Facultad de Informática
University of the Basque Country

Abstract. A system dynamics model reflecting the structure of the interaction between the two languages operating in the Basque Country has been built. People have been classified into three different groups depending on their knowledge of the language. These groups of population are subjected to a normal demographic evolution and to a linguistic interaction. The interaction among the populations is controlled by two major levels: the basque culture, and the development factors of the language. The only exogenous input to the model are political actions to raise or to decrease the development factors level. Although the model proves to be sensitive to these actions a delay time of about sixty years is to be expected in the response of the population.

1. INTRODUCTION

An emerging interest on the survival of minority languages can be observed in the last few years. The interaction between two languages coexisting in the same geographical area can be of different types (Sánchez Carrión 1982). A language have different levels of presence in social activity. At the bottom acts at a personal level, superior levels of action are the family level, the profesional one, a dialect, a national language and, finally, a standard of international culture. A full development of a language implys its presence at least in every level but the international one. When a minority language coexists with a majority one in the same geographical area, the majority language pushes down the minority one into lower and lower levels of activity. If there is no other nation where the language is dominant and of full presence its own survival is in question.

The case of the basque language in the Basque Country responds to this latter situation. All its geographical space is occupied either by Spanish or French. The survival of the language depends on whether or not the basque will be able to become a national language. Obviously the present model does not answer such a question. Its goal is very much modest. We are not linguists and if we have dared do it is because we think system dynamics modelling might be of help for other people. This model is only a first attempt to quantify some of the interactions in the sociolinguistic system.

2. AGGREGATED MODEL. BASIC MECHANISMS

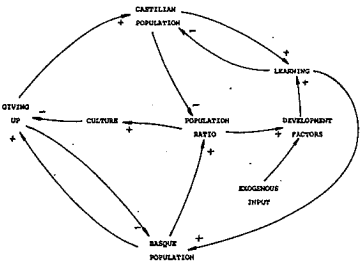
From a highly aggregated wiewpoint the use of whether one or the other language will evolve in time in consequence of two demographic evolutions interacting each other. These two demographies being respectively the population who knows (or uses) exclusively the dominant language and the one who knows and uses the minority language. In this latter case it is realistic to admit that this population knows the majority language too. That is to say, we are concerned with two populations being one of them monolingual and the other one bilingual.

The natural demography of both populations can be stablished, at least its model, as accuracely as wanted. We have not gone to great lenghts to approach it. What is much more difficult to decide and, on the other hand, it becomes essential to our goal is to stablish the structure of the interaction between both populations. We have not found in the literature any global hypothesis about the mechanisms governing the flows between them. We suppose any language is a dominant one because agents capable of transmitting and keeping on the language implicitly concur in its development. Inversely, we think that if a language is a disminished one is because those agents which are present in the dominant language do not appear, or they do in a proportion lesser than needed, in the diminished language. Consequently, to stablish the structure of our model we should explicit and make responsible to these agents for the deficit in use of the minority language.

The interaction between the castilian population and the basque population is produced through a double way. On the one hand a learning process takes place. This process is mainly produced among children who coming from castilian parents accede to a bilingual education. It is also produced among adults who like or need to know basque. But this learning process only takes place if some kind of factors which facilitate, motivate or even force the learning concur. In the model we refer to them as development factors. On the other hand, among the basque population a process of forgetting or giving up the language is produced. This abandon is in consequence of the lack of possibilities to a full vital activity in their language which brings about a disuse of it in daily life.

The percentage of activities which a person finds can be carried out in the minority language must be quantified. The greater will be this percentage the lesser will be the abandon of the language. This variable is called culture in the model.

The basic structure of the model is shown in figure 1. The castilian population flows to the basque population through a learning process. This flow is favoured by the development factors level. At the same time the basque population gives up using its language flowing to castilian population. The culture level restrains this flow. The basque culture is a creation of the basque population. More rigorously, granted our meaning for the level of culture, the creation depends on the adult basque to castilian population ratio. Although the development factors



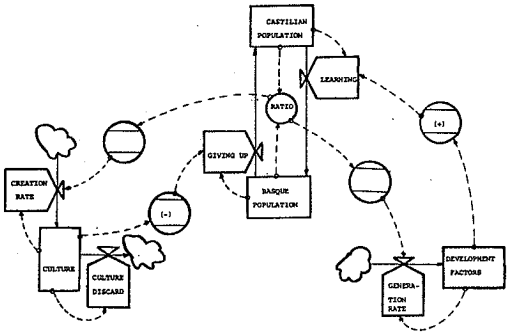


Fig. 1

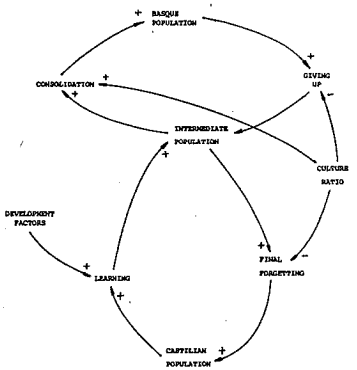


Fig. 2

Fig. 1 Basic structure of the model

Fig. 2 Basic causal diagram of the interaction among populations

also depend on the population ratio they are more sensitive to exogenous actions of political character. In the model that political action is the only exogenous input variable. The reference mode of the system is a simple one. An increase in the basque population towards a totally bilingual population or the practical disappearence of the diminished language is to be expected depending on whether the development factors reach or are unable to reach some critical value.

3. INTERMEDIATE POPULATION

Because of the socio-linguistic peculiarity of the basque society in which a considerable amount of the population has only a partial knowledge of the language, it seems necessary to take this situation into account in building up the model. So, it has been included a third population, refered in the model as intermediate population, which acts as intermediary in receiving the learning and giving up flows. Consequently, the model utilised the following three groups of populations:

- Basque-speaking population: Integrated by persons who understand and speak basque. It is a bilingual population.
- Castilian-speaking population: Integrated by persons who do not speak neither understand basque.
- Intermediate population: Integrated by persons coming from castilian-speaking population who have learnt basque or by persons coming from basque-speaking population who have missed it. It is integrated by persons who speak and understand basque with difficulty.

Figure 2 shows the basic causal diagram of the interaction among these populations. The flows among them are controled by the development factors and the culture ratio. The development factors control the learning flow which allows the castilian population to accede to intermediate population. The eventual incorporation of this intermediate population into basque population is supposed more dependent on the degree of basque culture, this is to say the culture ratio. Likewise, the culture ratio favours the final consolidation of the basque population what is translated into a decrease in the abandon flow.

4. CULTURE AND DEVELOPMENT FACTORS

As it has been already stated, the interaction flows among different groups of population are controled by two levels: culture and development factors. Although these two levels have a clear intuitive meaning they are difficult to quantify.

The culture is a level ranging from 0 to 100. It is considered that culture has reached its greatest value when any normal person has the posibility of implementing all its activity in basque in the same way as any normal person can develop its activity in the dominant language. So, it is not a question of an accumulation of erudition but to satisfy basic needs. That is why, in the model the growht of culture has been limited. Once

the threshold everybody can entirely live in his language is reached any additional increase of the level of culture is irrelevant to our purpose. Unlike the development factors level which admit an exogenous generation rate, the creation of culture is always endogenous to the system. The basque population is responsible for the creation of culture, its efficiency will depend upon their own culture ratio and will be helped of restrained by the development factors. Figure 3 shows on its rigth side the submodel of culture. The normal culture creation rate is afected by the population ratio, or in other words, a normal adjusting time would imply the whole population colaborating on it.

In figure 3 is also included the development factors submodel. These factors are used here as an aggregated measure of the elements which increase the possibilities to learn the language. That is to say, motivate the learning process and provide the resources for it. For instance, special laws to protect the language, creation of learning centers, communication media which use that language, etc. Its structure is such of a negative loop with a normal adjusting time of two generations. The adjusting time depends on the social pressure which, by its own, depends on the population ratio and on the current value of the development factors level. Unlike the level of culture, this level may increase or slump, in consequence of an exogenous input, at a relatively high speed. In fact, throughout history this variable has been, and keeps on being, goal of political actions.

5. DESAGGREGATION OF POPULATIONS

The demographic evolution of the different population groups calls for a desaggregation of each group into several levels. This is also needed to properly allocate the interpopulation flows. The aging range of each level has been chosen in such a way to have a clear meaning from the point of view of the learning of a language. The complete model can be seen in fig. 3.

Castilian population. This population has been desaggregated into the following levels:

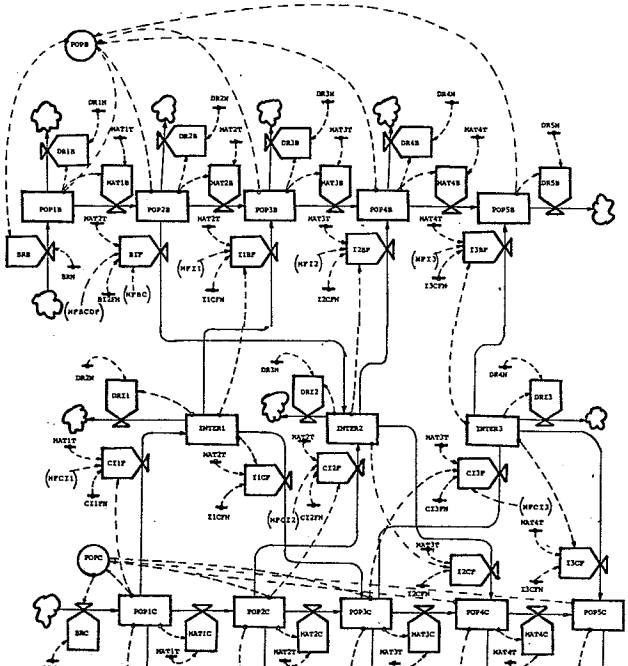
POP1C - Children ranging from 0 to 4 years old. They will learn their parents language. Currently many children go to preschoolar basque centers, and they may become intermediate population.

POP2C - Children from 5 to 14 years old. Period of compulsory education. The current education schemes allow a percentage of this population to know basque becoming also intermediate.

POP3C - Youngs from 15 to 29 years old. Learning of the language submited to a personal decission influenced by the development factors.

POP4C - Adults from 30 to 45 years old. We consider it is not of significance the learning flow in this level of age. Its interest is to pick up a part of the intermediate population.

POP5C - Adults older than 45 years.



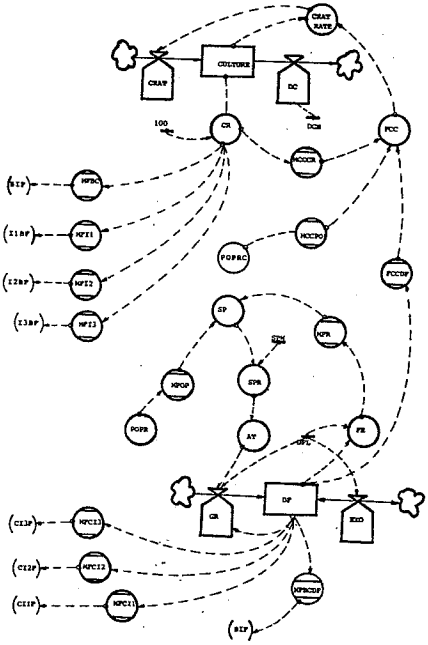


Fig. 3 Desaggregated model. On the right the submodel of culture and development factors.

Basque and intermediate population:

Like the castilian population, basque population has been desaggregated in five levels. This keeps on a paralelism between both populations which permits the flows between them to be controlled. The intermediate population is composed of three levels which stand for the range of ages of bifurcation to a final consolidation or missing of the language.

6. POLICIES IMPLEMENTED THROUGH MULTIPLIERS

The control of the flows among populations and the flows governing the levels of culture and development factors has been implemented by means of multipliers. These multipliers make explicit some hypothesis that we think are reasonably realistic but which have not been validated because of the lack of an apposite framework to refer it. We are not describing all of them in detail. Figure 4 shows the ones we consider important for understanding the model. There are three variables with a major importance in controlling the flows; the culture ratio, the development factors ratio and the population ratio.

Flows controlled by culture ratio

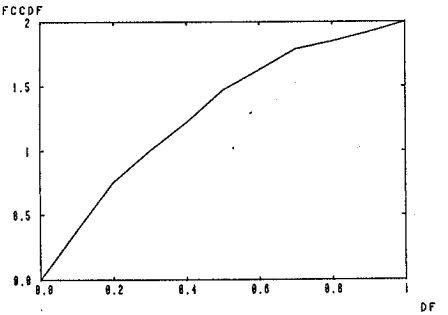
- Culture ratio controls the flow from basque population to castilian population through the MFBC multiplier. The initial condition for culture is 0.2. In that condition some more than 10 percent of the young population eventually abandons the language at fifteen due to some lack of possibilities for vital activity in it. If culture increases this abandon goes down until eventually stops when culture reaches its upper limit. In the most unfavorable conditions for culture twice the normal rate, that is 20 percent of the young population, will miss their language at arriving at fifteen.

- Inversely, culture ratio helps the final access from intermediate population to basque population. This effect is implemented in the model by the family of MFI multipliers. In the case shown in figure 4, culture ratio is able to triplicate the normal flow rate or to cut it off in the most unfavorable situation.

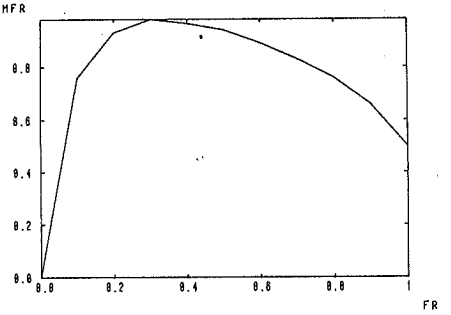
- Culture ratio is also decisive in controlling the development of the culture level. This effect is implemented by MCCCR. At the limits, a null value or a maximum value of culture make its creation impossible. This is consequent with the assumption made for the level of culture. It is assumed the creation of culture has a maximum value for culture ratio at about 0.65.

Flows controlled by population ratios

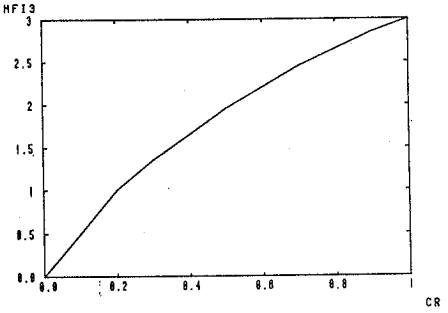
The creation of culture and the generation of development factors are controlled each other by population ratios. To control the creation of culture the ratio has been taken including only levels of adult population. To control the generation of development factors one aditional level of younger population has



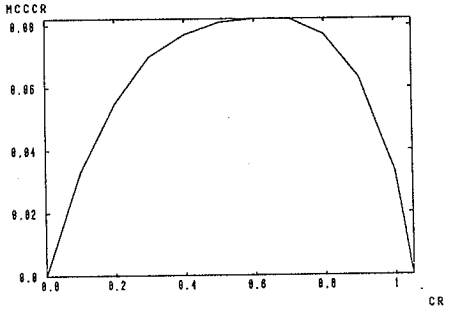
Creation of culture factor vs. development factors



Social pressure multiplier vs. factors ratio

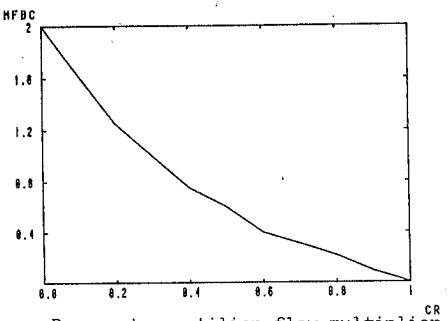


Flow from intermediate 3 to basque multiplier vs. culture ratio

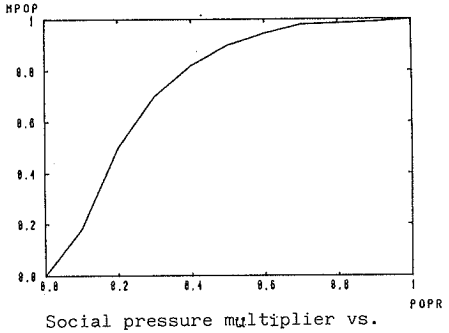


Creation of culture multiplier vs. culture ratio

Fig. 4



Basque to castilian flow multiplier vs. culture ratio



Social pressure multiplier vs. population ratio

been used. Figure 4 shows one of these multipliers. They reflect the hypothesis of a normal rate operating when everybody colaborates in the effort. The efficiency goes down as the population ratio decreases. Obviously, a total lack of basque population makes impossible any development.

Flows controlled by development factors ratio

- The development factors make easier the flow from castilian to intermediate population. Its quantitative effects will be different depending on the level of age they apply to, being maximum upon children. This assumption has been implemented by the group of multipliers MFCI. A very low value for the level of development factors might make impossible basque children to be educated in their mother language. Under these circumstances the development factors would increase the flow from basque to intermediate population through the MFBCDF multiplier.

- It is obvious that development factors should increase the efficiency of creation of culture rate. It is not clear the limit for such an increase. The model stablishs that present efficiency would double if a strong effort to increase the infrastructure for helping culture is made.

- Development factors ratio influences the social pressure which controls the adjusting time of the development factors (MFR). We suppose social pressure gets a maximum for values of the development factors ratio at about thirty percent of its theoretical limit. At this state the endogenous adjusting time would be 30 years (more or less one generation).

7. RUNS OF THE MODEL

Initial values for the levels of population have been elaborated from data of the Direction of Statistics of the Basque Government (Gobierno Vasco 1984) refered to the area of San Sebastian. Also reports from Siadeco (Siadeco 1983) have been consulted. The work of Ruiz Olabuenaga is a good reference for an understanding of the kinds of relationships of the basque population with its language (Ruiz Olabuenaga 1983). We have not found explicit data for the levels of culture and development factors. The normal rates influenced by these levels are also hypothesis of the modelers.

The model has been run over a time period of fifty years. Figure 5 a) shows the standard run of the model with no exogenous action. If present attitudes towards basque continued in time the model shows a continous exogenous increase of the development factors. Influenced by the development factors people flow from castilian to intermediate population an culture starts a very slowly increase which consolidates basque population. Some thirty years would be, perhaps, needed to realize the system is going in the right direction.

The system might be reinforced by exogenous actions. Figure 5 b) shows a run where the generation of development factors has been helped with a negative generation loop with an adjusting time of thirty years.

Helped by this action culture gets its normal standard value in forty years and population growths quickly towards a full bilingual situation.

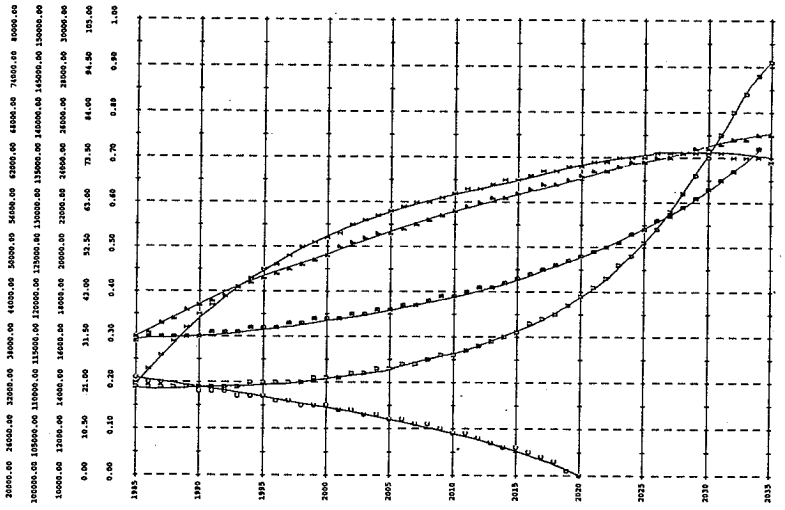
By the contrary a depletion of the development factors level might be forced from the outside. Figure 5 c) shows an extreme situation in what a linear external negative loop of depletion has been introduced. A five years adjusting time has been chosen for the test input. Culture steadily decreases over the whole period. Basque population remains steady for about thirty years to start thereafter a continuos decline. The fifty years time horizon of the model is not long enough to show clearly, in the level of population, the consequences of such an action. Its negative effect appears far ahead of the time the action is taken.

Finally, figure 5 d) shows the response of the system to a sudden step in the development factors level. The response of the culture is high-order delayed for about 25 years. The response of the basque population corresponds to a more or less third order delay with a delaying time of 60 years. The time horizon has been expanded in this simulation.

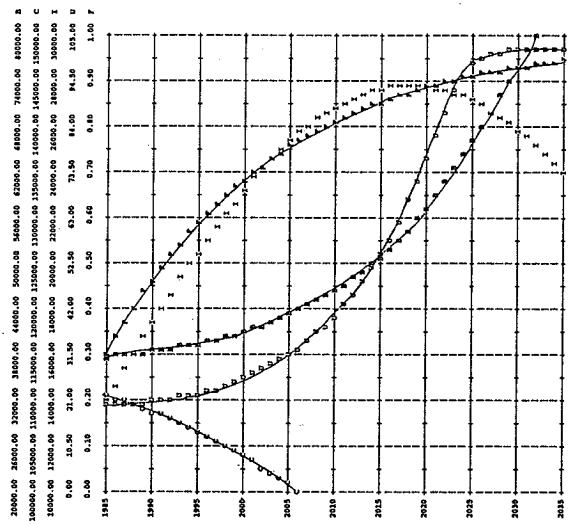
8. CONCLUSIONS

A system dynamics model of the sociolinguistic interaction between castilian and basque has been built. As far as we know, this is the first time an attempt to integrate the global interaction between both languages in a computer simulation model is made. Great efforts are being devoted nowadays to understand the mechanisms and the social processes involved in the diglosia of a language (Ruiz Olabuénaga 1985). We are not linguists so we hope our boldness will be forgiven. Our aim is to show, with the help of a running model, that computer simulation modelling may help in the research. System dynamics proves to be very apposite for it. Future improvement will come from those who can apply a different viewpoint and a more extensive background of knowledge.

Although a lot of statistical data are available, very few of them have been of interest to estimate the parameters used in this model. We can hope that this and future models will lead ulterior searching for data. We have found difficulties to stablish the structure of the submodel of culture. It has been also difficult to quantify the level. We think the hypothesis used has eventually proved to be operative. Our level of culture is a first aproximation to the accepted idea of different levels (layers) of 'presence' of a language in vital activity (Sánchez Carrión 1982). An ulterior development of this model towards a better fitting to that theory would be of interest.



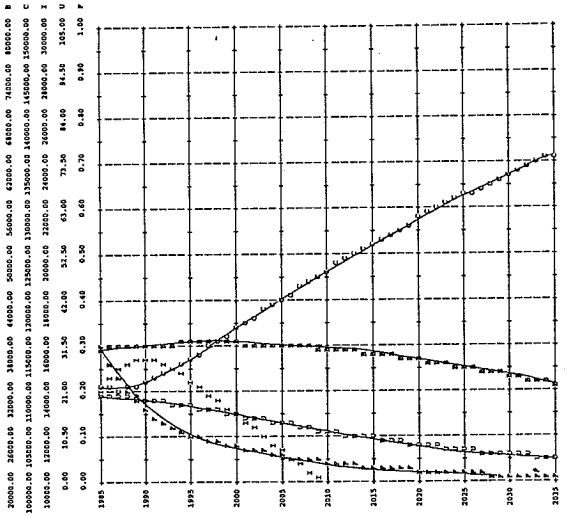
a)



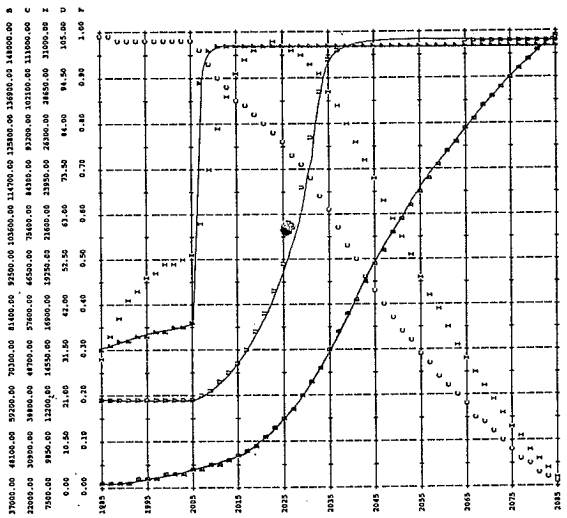
b)

Fig. 5 a) Standard run without exogenous input
b) Thirty years adjusting time linear input

I - Intermediate
B - Basque
C - Castilian
F - Development factors
U - Culture



c)



d)

Fig. 5 c) Five years adjusting time linear depletion input

d) Response to step

I - Intermediate
B - Basque
C - Castilian
F - Development factors
U - Culture

Another flaw of the present model is, probably, the treatment that intermediate population has received. The difficulty comes from the great complexity of the actual system. To classify population in three groups, basque as bilingual, intermediate as people who do not master the language and castilian, is an oversimplification of reality. Additional research is to be made for an apposite description of the population.

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APPENDIX 1

List of variables

LIST OF VARIABLES

POP1B	BASQUE POPULATION 1
POP2B	" " 2
POP3B	" " 3
POP4B	" " 4
POP5B	" " 5
BRB	BASQUE BIRTH RATE
BRN	BIRTH RATE NORMAL
DR1B	BASQUE DEATH RATE 1
DR2B	" " 2
DR3B	" " 3
DR4B	" " 4
DR5B	" " 5
DR1N	DEATH RATE NORMAL 1
DR2N	" " 2
DR3N	" " 3
DR4N	" " 4
DR5N	" " 5
MAT1B	BASQUE MATURATION RATE 1
MAT2B	" " 2
MAT3B	" " 3
MAT4B	" " 4
MAT1T	MATURATION TIME 1
MAT2T	" " 2
MAT3T	" " 3
MAT4T	" " 4
POPB	BASQUE POPULATION
BRC	CASTILIAN BIRTH RATE
DR1C	CASTILIAN DEATH RATE 1
DR2C	" " 2
DR3C	" " 3
DR4C	" " 4
DR5C	" " 5
MAT1C	CASTILIAN MATURATION RATE 1
MAT2C	" " 2
MAT3C	" " 3
MAT4C	" " 4
POP1C	CASTILIAN POPULATION 1
POP2C	" " 2
POP3C	" " 3
POP4C	" " 4
POP5C	" " 5
INTER1	INTERMEDIATE POPULATION 1
INTER2	" " 2
INTER3	" " 3
POPI	INTERMEDIATE POPULATION
CI1F	CASTILIAN TO INTERMEDIATE 1 FLOW
CI2F	" " 2 "
CI3F	" " 3 "
I1CF	INTERMEDIATE 1 TO CASTILIAN FLOW
I2CF	" 2 " "
I3CF	" 3 " "
CI1FN	CASTILIAN TO INTERMEDIATE 1 FLOW NORMAL
CI2FN	" " 2 "
CI3FN	" " 3 "
BI2FN	BASQUE TO INTERMEDIATE 2 FLOW NORMAL
I1CFN	INTERMEDIATE 1 TO CASTILIAN FLOW NORMAL
I2CFN	" 2 " "
I3CFN	" 3 " "
DRI1	DEATH RATE INTERMEDIATE 1
DRI2	" " 2
DRI3	" " 3
BIF	BASQUE TO INTERMEDIATE 1 FLOW
POPC	CASTILIAN POPULATION
I1BF	INTERMEDIATE 1 TO BASQUE FLOW
I2BF	INTERMEDIATE 2 TO BASQUE FLOW
I3BF	INTERMEDIATE 3 TO BASQUE FLOW
DF	DEVELOPMENT FACTORS
GR	GENERATION RATE
DFL	DEVELOPMENT FACTORS LIMIT
AT	ADJUSTING TIME
SPR	SOCIAL PRESSURE RATIO
SPN	SOCIAL PRESSURE NORMAL
SP	SOCIAL PRESSURE
FR	FACTORS RATIO
MFCI3	CASTILIAN TO INTERMEDIATE 3 MULTIPLIER FLOW
MFCI2	" " 2 "
MFCI1	" " 1 "
MFR	FACTORS RATIO MULTIPLIER
CULTURE	
DC	DISCARD
DCN	DISCARD NORMAL
CRATR	CREATION RATE
CR	CULTURE RATIO
CRAT	CREATION
MCCCR	CREATION CULTURE FROM CULTURE RATIO MULTIPLIER
MCCPOP	CREATION CULTURE FROM POPULATION MULTIPLIER
MCCDF	CREATION CULTURE FROM DEVELOPMENT FACTORS
FCC	FACTOR CREATION CULTURE
MFBC	BASQUE TO CASTILIAN FLOW MULTIPLIER
MFI1	INTERMEDIATE 1 FLOW MULTIPLIER
MFI2	" 2 "
MFI3	" 3 "
MPOP	POPULATION MULTIPLIER
POPR	POPULATION RATIO
TMFCI1	TABLE OF INTERMEDIATE 1 FLOW MULTIPLIER
TMFCI2	TABLE OF " 2 "
TMFCI3	" " 3 "
TMFBC	" BASQUE TO CASTILIAN FLOW MULTIPLIER
TMPOP	TABLE OF POPULATION MULTIPLIER
TMFR	TABLE OF FACTORS RATIO MULTIPLIER
TMFI1	" INTERMEDIATE 1 FLOW MULTIPLIER
TMFI2	" " 2 "
TMFI3	" " 3 "
TMCCPOP	" CREATION CULTURE FROM POPULATION MULTIPLIER
TMCCDF	" CREATION CULTURE FROM DEVELOPMENT FACTORS
TMCCCR1	" CREATION CULTURE FROM CULTURE RATIO MULTIPLIER 1
TMCCCR2	" CREATION CULTURE FROM CULTURE RATIO MULTIPLIER 2
POPRC	POPULATION RATIO TO CULTURE
MFBCDF	BASQUE TO CASTILIAN FROM DEVELOPMENT FACTORS MULTIPLIER
EAT1	ENDOGENOUS ADJUSTING TIME 1
EAT2	ENDOGENOUS ADJUSTING TIME 2

APPENDIX 2

Equations of the model

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L  POP1B.K=POP1B.J+DT*(BRB.JK-MAT1B.JK-DR1B.JK)
L  POP2B.K=POP2B.J+DT*(MAT1B.JK-BIF.JK-DR2B.JK-MAT2B.JK)
L  POP3B.K=POP3B.J+DT*(MAT2B.JK+I1BF.JK-DR3B.JK-MAT3B.JK)
L  POP4B.K=POP4B.J+DT*(MAT3B.JK+I2BF.JK-DR4B.JK-MAT4B.JK)
L  POP5B.K=POP5B.J+DT*(MAT4B.JK+I3BF.JK-DR5B.JK)

L  POP1C.K=POP1C.J+DT*(BRC.JK-MAT1C.JK-DR1C.JK-CI1F.JK)
L  POP2C.K=POP2C.J+DT*(MAT1C.JK-MAT2C.JK-DR2C.JK-CI2F.JK)
L  POP3C.K=POP3C.J+DT*(MAT2C.JK+I1CF.JK-CI3F.JK-MAT3C.JK-DR3C.JK)
L  POP4C.K=POP4C.J+DT*(MAT3C.JK+I2CF.JK-DR4C.JK-MAT4C.JK)
L  POP5C.K=POP5C.J+DT*(MAT4C.JK+I3CF.JK-DR5C.JK)

L  INTER1.K=INTER1.J+DT*(CI1F.JK-I1CF.JK-I1BF.JK-DRI1.JK)
L  INTER2.K=INTER2.J+DT*(CI2F.JK+BIF.JK-I2CF.JK-I2BF.JK-DRI2.JK)
L  INTER3.K=INTER3.J+DT*(CI3F.JK-I3CF.JK-I3BF.JK-DRI3.JK)

L  DF.K=DF.J+DT*(GR.JK+EXO.JK-EXO.JK)
L  CULTURE.K=CULTURE.J+DT*(CRAT.JK-DC.JK)

A  FR.K=DF.K/DFL
A  POPR.K=(POP3B.K+POP4B.K+POP5B.K)/(POP3B.K+POP4B.K+POP5B.K+POP3C.K+POP4C.K+POP5C.K)
A  POPB.K=POP1B.K+POP2B.K+POP3B.K+POP4B.K+POP5B.K
A  POPT.K=POP1C.K+POP2C.K+POP3C.K+POP4C.K+POP5C.K+INTER1.K+INTER2.K+INTER3.K
A  POPC.K=POP1C.K+POP2C.K+POP3C.K+POP4C.K+POP5C.K
A  POPI.K=INTER1.K+INTER2.K+INTER3.K
A  POPRC.K=(POP4B.K+POP5B.K)/(POP4B.K+POP5B.K+POP4C.K+POP5C.K)

A  CR.K=CULTURE.K/100
A  MCC1.K=TABLE(TMCC1,CR.K,0,0.5,0.05)
A  MCC2.K=TABLE(TMCC2,CR.K,0.55,1.05,0.05)
A  MCCCR.K=CLIP(MCC2.K,MCC1.K,CR.K,0.55)
A  MCCPOP.K=TABLE(TMCCPOP,POPRC.K,0,1,0.1)
A  FCCDF.K=TABLE(TFCCDF,DF.K,0,1,0.1)
A  FCC.K=MCCPOP.K*FCCDF.K*MCCCR.K
A  CRATRATE.K=CULTURE.K*FCC.K

A  MFCI1.K=TABLE(TMFCI1,DF.K,0,1,0.1)
A  MFCI2.K=TABLE(TMFCI2,DF.K,0,1,0.1)
A  MFBC.K=TABLE(TMFBC,CR.K,0,1,0.1)
A  MFBCDF.K=TABLE(TMFBCDF,CR.K,0,1,0.1)
A  MFCI3.K=TABLE(TMFCI3,DF.K,0,1,0.1)
A  MPOP.K=TABLE(TMPOP,POPR.K,0,1,0.1)
A  MFR.K=TABLE(TMFR,FR.K,0,1,0.1)
A  MFI1.K=TABLE(TMFI1,CR.K,0,1,0.1)
A  MFI2.K=TABLE(TMFI2,CR.K,0,1,0.1)
A  MFI3.K=TABLE(TMFI3,CR.K,0,1,0.1)

A  SP.K=MPOP.K*MFR.K
A  SPR.K=SP.K/SPN
A  AT.K=30/SPR.K
A  EAT1.K=CLIP(1000,30,TIME,2100)
A  EAT2.K=CLIP(1000,10000,TIME,2100)
A  X1.K=I1CFN*MFI1.K
A  X2.K=I2CFN*MFI2.K
A  X3.K=I3CFN*MFI3.K

R  BRB.KL=POPB.K*BRN
R  DR1B.KL=POP1B.K*DR1N
R  MAT1B.KL=(1/MAT1T)*(1-DR1N)*POP1B.K
R  DR2B.KL=POP2B.K*DR2N
R  MAT2B.KL=(1/MAT2T)*(1-DR2N)*(1-BI2FN*MFBC.K)*POP2B.K
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```
R  MAT3B.KL=(1/MAT3T)*(1-DR3N)*POP3B.K
R  DR3B.KL=POP3B.K*DR3N
R  MAT4B.KL=(1/MAT4T)*(1-DR4N)*POP4B.K
R  DR4B.KL=POP4B.K*DR4N
R  DR5B.KL=POP5B.K*DR5N

R  BRC.KL=POPT.K*BRN
R  MAT1C.KL=(1/MAT1T)*(1-DR1N)*(1-CI1FN*MFCI1.K)*POP1C.K
R  DR1C.KL=POP1C.K*DR1N
R  MAT2C.KL=(1/MAT2T)*(1-DR2N)*(1-CI2FN*MFCI2.K)*POP2C.K
R  DR2C.KL=POP2C.K*DR2N
R  MAT3C.KL=(1/MAT3T)*(1-DR3N)*(1-CI3FN*MFCI3.K)*POP3C.K
R  DR3C.KL=POP3C.K*DR3N
R  MAT4C.KL=(1/MAT4T)*(1-DR4N)*POP4C.K
R  DR4C.KL=POP4C.K*DR4N
R  DR5C.KL=POP5C.K*DR5N

R  CI1F.KL=(1/MAT1T)*CI1FN*MFCI1.K*(1-DR1N)*POP1C.K
R  BIF.KL=(1/MAT2T)*BI2FN*MFBC.K*MFBCDF.K*(1-DR2N)*POP2B.K
R  CI2F.KL=(1/MAT2T)*CI2FN*MFCI2.K*(1-DR2N)*POP2C.K
R  CI3F.KL=(1/MAT3T)*CI3FN*MFCI3.K*(1-DR3N)*POP3C.K
R  DRI1.KL=INTER1.K*DR2N
R  DRI2.KL=INTER2.K*DR3N
R  DRI3.KL=INTER3.K*DR4N
R  I1BF.KL=(1/MAT2T)*X1.K*(1-DR2N)*INTER1.K
R  I2BF.KL=(1/MAT3T)*X2.K*(1-DR3N)*INTER2.K
R  I3BF.KL=(1/MAT4T)*X3.K*(1-DR4N)*INTER3.K
R  I1CF.KL=(1/MAT2T)*(1-X1.K)*(1-DR2N)*INTER1.K
R  I2CF.KL=(1/MAT3T)*(1-X2.K)*(1-DR3N)*INTER2.K
R  I3CF.KL=(1/MAT4T)*(1-X3.K)*(1-DR4N)*INTER3.K

R  GR.KL=(1/AT.K)*(DFL-DF.K)
R  CRAT.KL=CRATRATE.K
R  DC.KL=CULTURE.K/DCN
R  EXO.KL=(1/EAT2.K)*(DFL-DF.K)
R  EXO.KL=(1/EAT1.K)*DF.K


N  POP1B=2149
N  POP2B=5922
N  POP3B=6606
N  POP4B=5880
N  POP5B=17122
N  POP1C=9154
N  POP2C=18583
N  POP3C=29274
N  POP4C=21122
N  POP5C=32333
N  DF=0.3
N  CULTURE=20
N  INTER1=3903
N  INTER2=5262
N  INTER3=4810

C  BRN=0.014
C  DR5N=0.030
C  CI1FN=0.3
C  BI2FN=0.1
C  CI2FN=0.3
C  CI3FN=0.3
C  DR1N=0.0005
C  DR2N=0.00012
C  DR3N=0.004
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C  DR4N=0.004
C  DFL=1
C  SPN=1
C  MAT1T=5
C  MAT2T=10
C  MAT3T=15
C  MAT4T=16
C  DCN=30
C  I1CFN=0.2
C  I2CFN=0.2
C  I3CFN=0.2

T  TMFCI1=0/0.5/0.8/1/1.2/1.4/1.65/2/2.3/2.8/3.33
T  TMFCI2=0/0.4/0.8/1/1.13/1.26/1.4/1.62/1.76/1.88/2
T  TMFBC=2/1.62/1.25/1/0.75/0.6/0.4/0.312/0.22/0.1/0.012
T  TMFBCDF=3/2.1/1.55/1.25/1/1/1/1/1/1
T  TMFCI3=0/0.4/0.8/1/1.13/1.26/1.4/1.62/1.76/1.88/2
T  TMPOP=0/0.18/0.5/0.7/0.82/0.9/0.945/0.98/0.985/0.99/1
T  TMFR=0/0.76/0.93/0.98/0.965/0.94/0.89/0.83/0.76/0.66/0.5
T  TMFI1=0/0.5/1/1.5/2/2.5/3/3.5/4/4.5/5
T  TMFI2=0/0.55/1/1.45/1.8/2.2/2.55/2.85/3.25/3.65/4
T  TMFI3=0/0.5/1/1.35/1.65/1.95/2.2/2.45/2.65/2.85/3
T  TMCCPOP=0/0.22/0.42/0.6/0.72/0.825/0.92/0.99/1/1/1
T  TFCCDF=0/0.38/0.75/1/1.22/1.47/1.63/1.79/1.85/1.92/2
T  TMCC1=0/0.022/0.033/0.048/0.055/0.066/0.070/0.074/0.077/0.079/0.081
T  TMCC2=0.0805/0.082/0.085/0.082/0.080/0.077/0.072/0.063/0.050/0.033/0

TIME=1985
SPEC DT=0.0625,PLTPER=1,PRTPER=1,LENGTH=50
PRINT (POPB,POPT,POPI,CULTURE,DF)

PLOT   POPB=BB(20000,60000),POPT=CC(100000,150000),POPI=II(10000,30000),
       CULTURE=UU(0,105),DF=FF(0,1)
```