

Effective coverage of stomach cancer prevention in Chile 2009-2024

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1. OBJECTIVES

Gastric cancer (GC) is the fifth most diagnosed malignant tumor worldwide, with South America—and Chile in particular—representing a critical hotspot for high mortality. This study evaluated the association between GC mortality and two preventive strategies in Chile: *H. pylori* (HP) eradication and opportunistic screening via upper gastrointestinal endoscopy (UGE).

2. METHODS

A cross-sectional, ecological study of the Chilean population was conducted for the 2009–2024 period.

We sourced population data from Instituto Nacional de Estadísticas, gastroenterology consultations and UGE production data from the Ministry of Health, HP treatments and opportunistic screenings data from Fondo Nacional de Salud, private insurance beneficiaries data from Superintendencia de Salud, and GC mortality data from the Ministry of Health.

The effective coverage framework was applied across the country's 29 Health Services (HS). The target population for HP treatment was the general population, and for GC diagnosis, incident cases among individuals aged 40+ were estimated using incidence-mortality ratios. Available capacity was measured by gastroenterology consultations and UGE production; utilization was measured by HP treatments and GC confirmations; and effectiveness was measured by GC deaths.

Metric	H. Pylori treatment	Opportunistic screening
Target population	All population	Incident cases 40+ years
Available Capacity	Gastroenterology consultations production	Upper gastrointestinal endoscopy production
Utilization	<i>H. pylori</i> treatments	Opportunistic screenings of symptomatic patients
Effectiveness	Mortality	Mortality

Using this metrics available, utilized and effective coverage by sex s , age range a , health service i and year t was calculated as¹:

¹ Available coverage was calculated for health service and year level only.

- $AvailableCoverage_{it} = AvailableCapacity_{it} / TargetPopulation_{it}$
- $UtilizationCoverage_{isat} = Utilization_{isat} / Target\ population_{isat}$
- $EffectiveCoverage_{isat} = Mortality_{isat} / Target\ population_{isat}$

Linear mixed models with random intercepts by HS were used to evaluate associations between utilization-availability and mortality-utilization. Covariates included sex, age group, rurality percentage, private insurance coverage (ISAPRE), and time period.

The effectiveness vs utilization model can be expressed as:

$$Y_{isat} = \beta_0 + \beta_1 \cdot Sex_s \cdot AgeRange_a + \beta_2 \cdot AgeRange_a \cdot Sex_s \cdot t + \beta_3 \cdot AgeRange_a \cdot Sex_s \cdot UtilizedCoverage_{isat} + \beta_4 \cdot Rurality_{it} + \beta_5 \cdot PrivateInsurance_{isat} + u_i + \epsilon_{isat}$$

Where:

- Y_{isat} represents *EffectiveCoverage* for population of sex s age group a in service i at year t .
- β_0 is the overall intercept.
- $Sex_{isat} \cdot AgeRange_{it}$ represents the interaction between Sex and AgeRange.
- $AgeRange_a \cdot Sex_s \cdot t$ represents the three-way interaction between AgeRange, Sex and year t .
- $AgeRange_a \cdot Sex_s \cdot UtilizedCoverage_{isat}$ represents the three-way interaction between AgeRange, Sex, and UtilizedCoverage.
- $Rurality_{it}$ is the percentage of rural population of the health service.
- $PrivateInsurance_{isat}$ is the percentage of population with private health insurance.
- u_i represents the random intercept for each health service i , accounting for unobserved heterogeneity between services. $u_i \sim N(0, \sigma_u^2)$.
- ϵ_{isat} is the residual error term, assumed to be normally distributed with mean 0 and constant variance. $\epsilon_{isat} \sim N(0, \sigma_\epsilon^2)$.

The utilization vs availability model can be expressed as:

$$Y_{it} = \beta_0 + \beta_1 \cdot AvailableCoverage_{it} + \beta_2 \cdot Rurality_{it} + \beta_5 \cdot PrivateInsurance_{it} + \beta_3 \cdot t + u_i + \epsilon_{it}$$

Where

- Y_{it} represents *UtilizationCoverage* for population in service i at year t .
- β_0 is the overall intercept.
- $AvailableCoverage_{it}$ is the available coverage
- $Rurality_{it}$ is the percentage of rural population of the health service.
- $PrivateInsurance_{it}$ is the percentage of population with private health insurance.
- u_i represents the random intercept for each health service i , accounting for unobserved heterogeneity between services. $u_i \sim N(0, \sigma_u^2)$.
- ϵ_{it} is the residual error term, assumed to be normally distributed with mean 0 and constant variance. $\epsilon_{it} \sim N(0, \sigma_\epsilon^2)$.

3. RESULTS

3.1. Participants

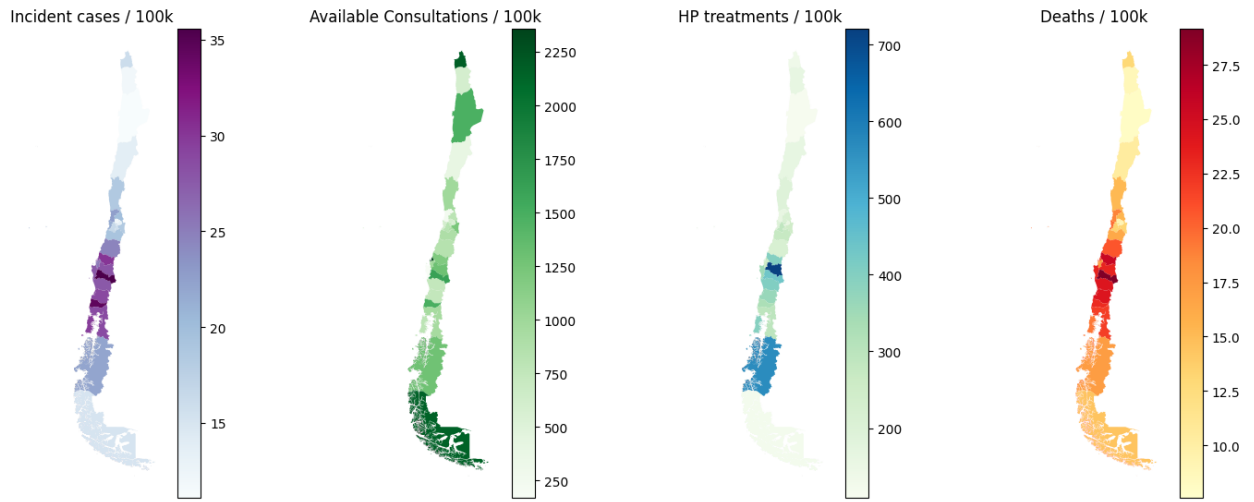
Macro-region	Health Service	Person-years	Population 2024	% Population 2024
Norte	Arica y Parinacota	3798989	261779	1.3
	Tarapacá	5535602	406287	2.0
	Antofagasta	10141825	718232	3.6
	Atacama	4856518	319992	1.6
Centro Norte	Coquimbo	12612287	879267	4.4
	Valparaíso San Antonio	8254787	547982	2.7
	Viña del Mar Quillota	17457538	1182912	5.9
	Aconcagua	4343598	293062	1.5
Centro	Metropolitano Norte	16504902	1244109	6.2
	Metropolitano Occidente	20451309	1390289	6.9
	Metropolitano Central	19845747	1443283	7.2
	Metropolitano Oriente	21935166	1522007	7.6
	Metropolitano Sur	19561487	1310176	6.5
	Metropolitano Sur Oriente	23179847	1519737	7.6
Centro Sur	Del Libertador B.O'Higgins	15095276	1018451	5.1
	Del Maule	17407868	1171982	5.8
Sur	Ñuble	7981322	521711	2.6
	Concepción	10864590	713112	3.6
	Talcahuano	5781162	365561	1.8
	Biobío	6615386	429661	2.1
	Arauco	2784394	177891	0.9
	Araucanía Norte	3408312	216365	1.1
Extremo Sur	Araucanía Sur	12441686	815799	4.1
	Los Rios	6355259	412786	2.1
	Osorno	3912629	250192	1.2
	Del Reloncaví	7080283	478064	2.4
	Aysén	1675897	108538	0.5
	Magallanes	2708269	181116	0.9
	Chiloé	2845490	183915	0.9
Total		295437425	20084258	100.0

3.2. Outcomes

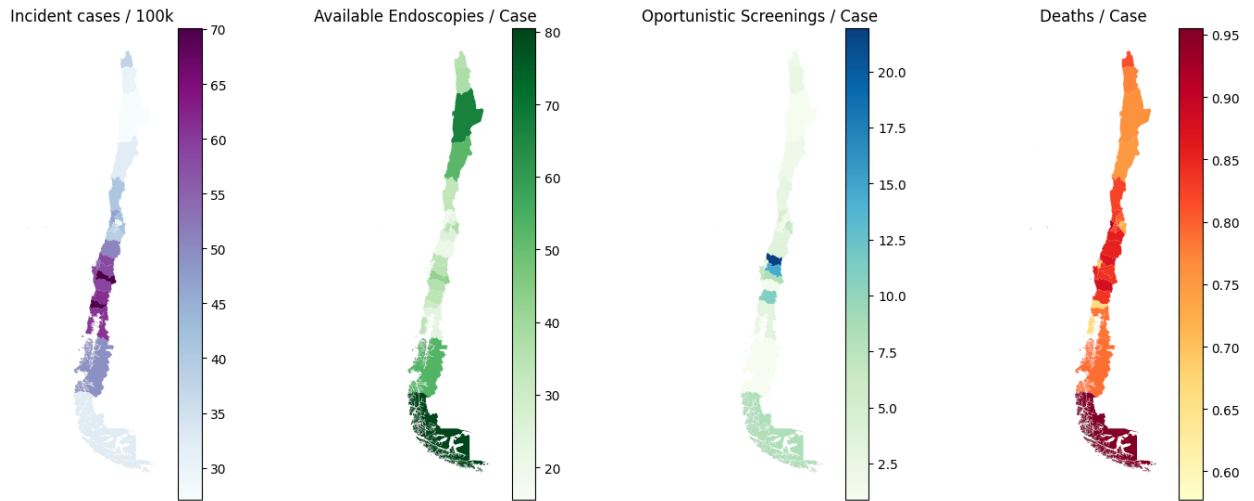
Macro Region	Health Service	Gastric Cancer Cases	Gastro enterology Consultations	Upper Gastro intestinal Endoscopies	Opportunistic Endoscopic Screenings	H. pylori Treatments	Gastric Cancer Deaths
Norte	Arica y Parinacota	577	75444	18133	580	1784	456
	Tarapacá	706	25011	23060	705	4277	621
	Antofagasta	1251	109935	51332	1094	7795	979
	Atacama	767	16925	32282	923	3501	633
Centro Norte	Coquimbo	2373	87247	75105	3747	12311	2131
	Valparaíso	1941	68796	49205	6172	8419	1785
	San Antonio						
	Viña del Mar Quillota	4196	69414	69529	19683	13886	3482
	Aconcagua	914	26302	21348	1170	4944	727
Centro	Metropolitano Norte	2688	98388	61870	976	23414	2069
	Metropolitano Occidente	3677	180133	127480	4687	35147	3147
	Metropolitano Central	3120	150487	84702	6357	13930	2077
	Metropolitano Oriente	3320	132783	97310	24898	21122	2439
	Metropolitano Sur	3578	150820	97292	11751	25826	3120
	Metropolitano Sur Oriente	4533	224666	120458	35901	35689	3356
Centro Sur	Del Libertador B.O'Higgins	2982	91083	62493	5787	21108	2569
	Del Maule	4519	123732	113558	14581	16666	4048
Sur	Ñuble	2287	78352	85045	37379	19913	2023
	Concepción	2800	78404	56821	4515	15008	2119
	Talcahuano	1623	105633	36239	4746	5972	1472
	Biobío	2065	71939	48938	13434	18126	1820
	Arauco	851	3277	13796	4539	5514	743
	Araucanía Norte	1181	15576	34873	5250	7358	1043
Extremo Sur	Araucanía Sur	3217	66844	92402	3210	23867	2942
	Los Rios	2034	47978	55107	17430	11176	1652
	Osorno	1225	55050	33472	2081	6389	966
	Del Reloncaví	1877	49278	40331	3121	9160	1469
	Aysén	408	14664	18921	401	3497	350
	Magallanes	584	51590	26756	1492	2034	482
	Chiloé	721	4833	22940	1048	8090	591
Total		62015	2274584	1670798	237658	385923	51311

3.3. Coverage maps

HP treatment Coverage by Health Service (2022-2024)



GC Opportunistic Screening Coverage by Health Service (2022-2024)



3.4. HP Mixed Models

Utilization vs Availability Coverage

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Mixed Linear Model Regression Results
=====
Model:                MixedLM          Dependent Variable:   CoberturaUtHP
No. Observations:    145              Method:              REML
No. Groups:          29                Scale:              5039.7718
Min. group size:     5                Log-Likelihood:    -832.8189
Max. group size:     5                Converged:         Yes
Mean group size:     5.0
=====

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	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	-44308.030	2908.329	-15.235	0.000	-50008.249	-38607.810
CoberturaDispHP	0.013	0.016	0.805	0.421	-0.018	0.044
PorcPoblacionRural	4.187	0.843	4.969	0.000	2.535	5.838
Periodo	22.003	1.444	15.242	0.000	19.174	24.833
idServicio Var	1439.358	10.760				

Utilization vs Effective Coverage

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Mixed Linear Model Regression Results
=====
Model:                MixedLM          Dependent Variable:   CoberturaEfHP
No. Observations:    1740             Method:              REML
No. Groups:          29                Scale:              662.7230
Min. group size:     60                Log-Likelihood:    -8171.9974
Max. group size:     60                Converged:         Yes
Mean group size:     60.0
=====

```

	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	-6203.971	1498.229	-4.141	0.000	-9140.446	-3267.495
RangoEdad4080[T.[40, 50]]	3738.559	2010.196	1.860	0.063	-201.353	7678.470
RangoEdad4080[T.[50, 60]]	6448.646	2032.607	3.173	0.002	2464.809	10432.483
RangoEdad4080[T.[60, 70]]	14182.333	2063.457	6.873	0.000	10138.032	18226.634
RangoEdad4080[T.[70, 80]]	28506.279	2025.463	14.074	0.000	24536.444	32476.115
RangoEdad4080[T.[80, 120]]	29043.281	1945.220	14.931	0.000	25230.719	32855.843
Sexo[T.Mujer]:RangoEdad4080[[0, 40]]	1268.729	2028.303	0.626	0.532	-2706.672	5244.130
Sexo[T.Mujer]:RangoEdad4080[[40, 50]]	-571.514	1934.759	-0.295	0.768	-4363.572	3220.544
Sexo[T.Mujer]:RangoEdad4080[[50, 60]]	-3927.805	1996.897	-1.967	0.049	-7841.650	-13.960
Sexo[T.Mujer]:RangoEdad4080[[60, 70]]	-7825.307	2094.961	-3.735	0.000	-11931.356	-3719.258
Sexo[T.Mujer]:RangoEdad4080[[70, 80]]	-17138.463	1991.033	-8.608	0.000	-21040.816	-13236.110
Sexo[T.Mujer]:RangoEdad4080[[80, 120]]	-12608.412	1822.102	-6.920	0.000	-16179.666	-9037.159
RangoEdad4080[[0, 40]]:Sexo[Hombre]:Periodo	3.049	0.744	4.101	0.000	1.592	4.507
RangoEdad4080[[40, 50]]:Sexo[Hombre]:Periodo	1.195	0.688	1.737	0.082	-0.153	2.543
RangoEdad4080[[50, 60]]:Sexo[Hombre]:Periodo	-0.136	0.705	-0.193	0.847	-1.517	1.245
RangoEdad4080[[60, 70]]:Sexo[Hombre]:Periodo	-3.945	0.731	-5.394	0.000	-5.378	-2.512
RangoEdad4080[[70, 80]]:Sexo[Hombre]:Periodo	-10.988	0.691	-15.893	0.000	-12.343	-9.633
RangoEdad4080[[80, 120]]:Sexo[Hombre]:Periodo	-11.196	0.630	-17.770	0.000	-12.431	-9.961
RangoEdad4080[[0, 40]]:Sexo[Mujer]:Periodo	2.423	0.718	3.377	0.001	1.017	3.829
RangoEdad4080[[40, 50]]:Sexo[Mujer]:Periodo	1.482	0.695	2.134	0.033	0.121	2.843
RangoEdad4080[[50, 60]]:Sexo[Mujer]:Periodo	1.809	0.723	2.503	0.012	0.392	3.225
RangoEdad4080[[60, 70]]:Sexo[Mujer]:Periodo	-0.083	0.767	-0.109	0.913	-1.588	1.421
RangoEdad4080[[70, 80]]:Sexo[Mujer]:Periodo	-2.546	0.728	-3.498	0.000	-3.973	-1.120
RangoEdad4080[[80, 120]]:Sexo[Mujer]:Periodo	-5.026	0.663	-7.578	0.000	-6.325	-3.726
RangoEdad4080[[0, 40]]:Sexo[Hombre]:CoberturaUtHP	-0.307	0.091	-3.388	0.001	-0.484	-0.129
RangoEdad4080[[40, 50]]:Sexo[Hombre]:CoberturaUtHP	-0.071	0.029	-2.476	0.013	-0.127	-0.015
RangoEdad4080[[50, 60]]:Sexo[Hombre]:CoberturaUtHP	-0.035	0.021	-1.649	0.099	-0.076	0.007
RangoEdad4080[[60, 70]]:Sexo[Hombre]:CoberturaUtHP	0.014	0.017	0.866	0.386	-0.018	0.047
RangoEdad4080[[70, 80]]:Sexo[Hombre]:CoberturaUtHP	0.025	0.015	1.670	0.095	-0.004	0.054
RangoEdad4080[[80, 120]]:Sexo[Hombre]:CoberturaUtHP	0.087	0.021	4.116	0.000	0.046	0.128
RangoEdad4080[[0, 40]]:Sexo[Mujer]:CoberturaUtHP	-0.114	0.037	-3.075	0.002	-0.187	-0.041
RangoEdad4080[[40, 50]]:Sexo[Mujer]:CoberturaUtHP	-0.028	0.011	-2.469	0.014	-0.050	-0.006
RangoEdad4080[[50, 60]]:Sexo[Mujer]:CoberturaUtHP	-0.028	0.009	-3.102	0.002	-0.046	-0.010
RangoEdad4080[[60, 70]]:Sexo[Mujer]:CoberturaUtHP	-0.020	0.010	-1.998	0.046	-0.039	-0.000
RangoEdad4080[[70, 80]]:Sexo[Mujer]:CoberturaUtHP	-0.014	0.012	-1.140	0.254	-0.037	0.010
RangoEdad4080[[80, 120]]:Sexo[Mujer]:CoberturaUtHP	0.002	0.026	0.094	0.925	-0.049	0.054
PorcPoblacionRural	1.918	0.345	5.557	0.000	1.241	2.594
PorcIsapre	2.217	0.231	9.601	0.000	1.765	2.670
idServicio Var	598.315	6.984				

3.5. UGE Mixed Models

Utilization vs Availability Coverage

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Mixed Linear Model Regression Results
=====
Model:                MixedLM      Dependent Variable:  CoberturaUtCG
No. Observations:    145          Method:              REML
No. Groups:          29           Scale:               2.0900
Min. group size:     5            Log-Likelihood:     -315.6189
Max. group size:     5            Converged:           Yes
Mean group size:     5.0
=====

```

	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	-227.590	64.092	-3.551	0.000	-353.208	-101.972
CoberturaDispCG	0.048	0.018	2.703	0.007	0.013	0.084
PorcPoblacionRural	0.012	0.070	0.168	0.867	-0.125	0.148
PorcIsapre	-0.016	0.077	-0.202	0.840	-0.166	0.135
Periodo	0.114	0.032	3.603	0.000	0.052	0.176
idServicio Var	12.808	2.909				

Utilization vs Effective Coverage

```

Mixed Linear Model Regression Results
=====
Model:                MixedLM      Dependent Variable:  CoberturaEfCG
No. Observations:    1448          Method:              REML
No. Groups:          29           Scale:               0.0359
Min. group size:     48            Log-Likelihood:     206.4039
Max. group size:     50            Converged:           Yes
Mean group size:     49.9
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```

	Coef.	Std.Err.	z	P> z	[0.025	0.975]
Intercept	14.479	7.584	1.909	0.056	-0.385	29.343
RangoEdad4080[T.[50, 60]]	-0.158	10.712	-0.015	0.988	-21.154	20.837
RangoEdad4080[T.[60, 70]]	5.802	10.688	0.543	0.587	-15.145	26.750
RangoEdad4080[T.[70, 80]]	8.225	10.723	0.767	0.443	-12.792	29.242
RangoEdad4080[T.[80, 120]]	-16.185	10.693	-1.514	0.130	-37.142	4.773
Sexo[T.Mujer]:RangoEdad4080[[40, 50]]	-5.303	10.669	-0.497	0.619	-26.214	15.607
Sexo[T.Mujer]:RangoEdad4080[[50, 60]]	-4.962	10.753	-0.461	0.645	-26.038	16.115
Sexo[T.Mujer]:RangoEdad4080[[60, 70]]	2.712	10.719	0.253	0.800	-18.298	23.721
Sexo[T.Mujer]:RangoEdad4080[[70, 80]]	-5.343	10.757	-0.497	0.619	-26.426	15.740
Sexo[T.Mujer]:RangoEdad4080[[80, 120]]	8.737	10.796	0.809	0.418	-12.423	29.898
RangoEdad4080[[40, 50]]:Sexo[Hombre]:Periodo	-0.007	0.004	-1.819	0.069	-0.014	0.001
RangoEdad4080[[50, 60]]:Sexo[Hombre]:Periodo	-0.007	0.004	-1.783	0.075	-0.014	0.001
RangoEdad4080[[60, 70]]:Sexo[Hombre]:Periodo	-0.010	0.004	-2.570	0.010	-0.017	-0.002
RangoEdad4080[[70, 80]]:Sexo[Hombre]:Periodo	-0.011	0.004	-2.858	0.004	-0.018	-0.003
RangoEdad4080[[80, 120]]:Sexo[Hombre]:Periodo	0.001	0.004	0.361	0.718	-0.006	0.009
RangoEdad4080[[40, 50]]:Sexo[Mujer]:Periodo	-0.004	0.004	-1.137	0.256	-0.012	0.003
RangoEdad4080[[50, 60]]:Sexo[Mujer]:Periodo	-0.004	0.004	-1.139	0.255	-0.012	0.003
RangoEdad4080[[60, 70]]:Sexo[Mujer]:Periodo	-0.011	0.004	-2.919	0.004	-0.018	-0.004
RangoEdad4080[[70, 80]]:Sexo[Mujer]:Periodo	-0.008	0.004	-2.144	0.032	-0.016	-0.001
RangoEdad4080[[80, 120]]:Sexo[Mujer]:Periodo	-0.003	0.004	-0.776	0.438	-0.011	0.005
RangoEdad4080[[40, 50]]:Sexo[Hombre]:CoberturaUtCG	0.012	0.003	3.348	0.001	0.005	0.018
RangoEdad4080[[50, 60]]:Sexo[Hombre]:CoberturaUtCG	0.013	0.006	2.164	0.030	0.001	0.025
RangoEdad4080[[60, 70]]:Sexo[Hombre]:CoberturaUtCG	0.021	0.009	2.429	0.015	0.004	0.038
RangoEdad4080[[70, 80]]:Sexo[Hombre]:CoberturaUtCG	0.023	0.011	2.049	0.040	0.001	0.045
RangoEdad4080[[80, 120]]:Sexo[Hombre]:CoberturaUtCG	0.022	0.014	1.587	0.112	-0.005	0.049
RangoEdad4080[[40, 50]]:Sexo[Mujer]:CoberturaUtCG	0.002	0.001	2.799	0.005	0.001	0.004
RangoEdad4080[[50, 60]]:Sexo[Mujer]:CoberturaUtCG	0.003	0.001	2.697	0.007	0.001	0.005
RangoEdad4080[[60, 70]]:Sexo[Mujer]:CoberturaUtCG	0.003	0.002	1.611	0.107	-0.001	0.007
RangoEdad4080[[70, 80]]:Sexo[Mujer]:CoberturaUtCG	0.005	0.004	1.352	0.176	-0.002	0.012
RangoEdad4080[[80, 120]]:Sexo[Mujer]:CoberturaUtCG	0.026	0.007	3.557	0.000	0.011	0.040
PorcPoblacionRural	0.001	0.001	0.549	0.583	-0.002	0.003
PorcIsapre	-0.002	0.001	-1.478	0.139	-0.005	0.001
idServicio Var	0.004	0.009				