UNIVERSIDAD
DE SANTIAGO
DE CHILE

KNOWLEDGE-BASED CAPITAL AND ECONOMIC DEVELOPMENT IN LATIN AMERICA, 1990 - 2016

LAKLEMS (André Hofman)

WorldKLEMS Conference
October 13, 2022
Manchester, England

LAKLEMS
CRECIMIENTO ECONÓMICO Y
PRODUCTIVIDAD EN AMÉRICA LATINA

UNIVERSIDAD
DE SANTIAGO
DE CHILE

Abstract

The importance of knowledge-based capital in economic development in a group of eight Latin American (LA) countries, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Honduras, Mexico and Peru is compared with Spain and the United States.

The comparison was possible by the release of the KLEMS database for the Latin American countries and the EU KLEMS database that included the United States and Spain.

It uses an approach in measuring the knowledge intensity of economies that is different to those based on the aggregation of industries according to selected indicators such as research and development (R&D) expenditure or labor force skills.

Instead, the approach is rooted in the growth accounting methodology, determining the contribution of each individual factor of production (capital and labor) according to the services it provides.

This methodology will be applied to the above-mentioned LA countries and to the United States and Spain as benchmarks.

The period covered is 1990–2016.

Introduction

This article provides an alternative approach for measuring the knowledge economy. It follows the growth accounting methodology as developed by Jorgenson and associates (1987, 1995, 2005), which is applied to a set of eight Latin American countries, the US and Spain for the period 1995–2016.

The Knowledge Economy is the term applied to describe an economy where a considerable share of production is based on accumulated knowledge. The knowledge economy has grown in importance in recent decades, and is an important source of economic growth and competitiveness in developed and developing economies.

Introduction

How is a knowledge-based economy measured?

The most common approach is to identify the activities or sectors with more R&D investment and highly qualified employment, and calculate their contribution to GDP and employment in the economy.

Based on this approach, the OECD usually refers to knowledge economy as digital economy, highlighting ICT-intensive sectors, such as, e-commerce, transport, education, health, etc.

Other approaches build indexes (i.e. Digital Economy and Society (Eurostat DESI Index) or KEI (Knowledge Economy Index), World Bank) based on various indicators on ICT use, human capital, information infrastructures, etc.

Methodology

- This paper proposes a methodology to compute the knowledge content of an economy based on more accurate and disaggregated measurements of human and physical capital services.
- To compute the size and composition of the knowledge economy, two definitions of knowledge-based inputs are used, one broader and one more restrictive.
- In the first, ICT and machinery and equipment assets are included as capital inputs and the highest and medium levels of educational attainment as labor inputs.
- In the more restricted version only ICT assets are included as knowledge-based capital and higher levels of educational attainment as knowledge-intensive labor.
- Once the knowledge-based inputs have been identified according to the two approaches, we quantify the portion of income that remunerates the services that these factors provide (capital and labor compensation, in KLEMS terminology) and, by extension, their contribution to GVA.

Methodology

Assuming that there are m types of labor and n types of capital and some of these provide knowledge services and others do not, let L_{ij} be the amount of labor of type i used in sector j; K_{hj} the amount of capital of type h used in the same sector j, P_{ij}^{L} is the unitary wage paid for the labor of type i in sector j; and P_{hj}^{K} is the user cost of type h capital in sector j. Defining the value added in real terms produced by sector j as V_j and being P_j^V its price, the value added of sector j in nominal terms (V_j P_j^V) is distributed between the different inputs included in the production process so that,

$$\mathrm{V}_j P_j^V = \sum_{i=1}^{m} \mathrm{L}_{ij} * P_{ij}^{L} + \sum_{h=1}^{n} \mathrm{K}_{hj} * P_{hj}^{K} \qquad [1]$$

Let us assume that the price of the amount used for each type of labor depends on its productivity, and that the basis for differences in productivity is the human capital that each type contains. Under these hypotheses, wages can approximate the economic value of the amount of knowledge per unit of each type of labor. According to this criterion, we can consider that the type of labor that offers a lower wage (for workers with lower education levels) does not incorporate knowledge. While the other types of labor do incorporate knowledge, though at different rates according to the number of years or level of education. If we generalize to allow *f* type of low-skilled labor, the value of labor is decomposed into two parts, the second of which measures the value of human capital services:

$$\sum_{i=1}^{m} \mathrm{L}_{ij} * P_{ij}^{L} = \sum_{i=1}^{f} \mathrm{L}_{ij} * P_{ij}^{L} + \sum_{i=f+1}^{m} \mathrm{L}_{ij} * P_{ij}^{L} \quad [2]$$

Thus, the value of knowledge incorporated through labor (knowledge-intensive labor, KIL) would be given by:

$$\mathrm{KIL}_j = \sum_{i=f+1}^{m} \mathrm{L}_{ij} * P_{ij}^{L} \quad [3]$$

We assume that the content of knowledge in assets increases proportionately with its user cost. We use as a starting point the hypothesis that assets with a lower user cost do not incorporate knowledge in a significant way, while assets with a higher user cost do. Therefore, as aforementioned, we can assume that machinery and equipment do incorporate knowledge (although with the relative intensity reflected by their user cost, e.g., much higher in ICT assets) or we can follow a more restrictive view for capital which considers that only ICT and intangible assets incorporate knowledge in the production process.

The value added generated by physical capital is broken down into two broad categories: those that do not incorporate knowledge significantly (*g* assets) and those that do (*n-g* assets):

$$\Sigma_{h=1}^{n} \mathrm{K}_{h_j} * \mathrm{P}_{hj}^{K} = \Sigma_{h=1}^{g} \mathrm{K}_{h_J} * \mathrm{P}_{hj}^{K} + \Sigma_{h=g+1}^{n} \mathrm{K}_{h_J} * \mathrm{P}_{hj}^{K} \quad [4]$$

Then, the value of knowledge incorporated through physical assets (*knowledge-intensive capital, KIK*) would be given by:

$$\mathrm{KIK}_j = \Sigma_{h=g+1}^{n} \mathrm{K}_{h_J} * \mathrm{P}_{hj}^{K} \quad [5]$$

And the value of knowledge-intensive factors or value added based on knowledge (*knowledge-intensive value, KIV_j*) of activity *j* will therefore be:

$$\mathrm{KVK}_j = \mathrm{KIL}_j + \mathrm{KIK}_j \qquad [6]$$

The relative knowledge intensity *(%KIV_j)* of activity *j* is defined as

$$\%\mathrm{KIV}_j = {}^{\mathrm{KIV}_j}/_{V_j P_j^v} = \left[\mathrm{KIL}_j + \mathrm{KIK}_j\right] / V_j P_j^v \qquad [7]$$

Given the knowledge content of each industry, the knowledge intensity of an economy depends on the weight of the various branches in the aggregate. If *q* industries exist, the knowledge intensity of the economy as a whole (%*KIV*) is defined as,

$$\%\mathrm{KIV} \;=\; \sum_{j=1}^{q} \%\, KIV_j \left[\mathrm{V}_j P_j^V \,/\, \sum_{j=1}^{q} V P^V\right] \qquad [8]$$

The exercises carried out in this article, using LA KLEMS data, adopt the two approaches (the restrictive and the broader one) to measuring the knowledge economy presented in this section. That is, for labor we will consider high- and medium-skilled workers (higher and upper secondary education) as knowledge intensive and also only high-skilled workers, and for capital, we will compare the results obtained when considering ICT and machinery and equipment capital as knowledge-based assets with a more restrictive version which considers ICT capital as the only component of knowledge-based capital.

Statistical data: sources and coverage

- The paper uses a new database for eight Latin American countries for which this information was not previously available and the eight countries are compared with those of the US and Spain, which are used as benchmarks.
- The period covered is 1995 to 2016, the latest year for which data are available for all the countries. The information comes from the most up-to-date releases of EU KLEMS and LA KLEMS.
- The estimates of knowledge intensity following the methodology described above are mainly based on data from KLEMS databases: LA KLEMS for the eight Latin American countries, EU KLEMS for Spain and the United States.
- These databases contain information by industry on variables related to productivity and economic growth: value added, output, employment and skills, gross capital formation by assets and accumulated capital, capital and labor compensation, etc.

Statistical data: sources and coverage

- At the moment, LA KLEMS data is available for the period 1990-2016, whereas EU KLEMS database covers the period 1995–2016, although the coverage varies depending on the country, the selected variable and its detail.
- Table 1 shows the disaggregation for the gross fixed capital formation and capital stock assets.
- Table 2 shows the nine economic activities in which Gross Value Added is disaggregated.

Statistical data: sources and coverage

Table 1. Capital assets considered for the estimation of knowledge-based GVA

KLEMS assets
ICT assets
Software
Computing equipment
Communication equipment
Non-ICT assets
Transport equipment
Machinery and Equipment (excluding ICT)
Non-residential structures
Residential structures
Research and development (R&D)
Other Intellectual Property Products

Source: Own elaboration.

Table 2. Industry classification (available for all countries)

Agriculture, forestry, and fishing
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale and retail trade; accommodation and food service
Transportation and communications
Financial, real estate and business services
Other services

Source: Own elaboration.

Table 3. Descriptive statistics

a) Gross fixed capital formation

a.1) GFCF structure by assets, average 1995-2016 (%)	Chile	Colombia	Costa Rica	El Salvador	Honduras	México	Perú	Rep. Dominicana	Spain	US
ICT	**9,33**	**9,97**	**8,24**	**6,83**	**7,52**	**4,65**	**2,53**	**5,57**	**10,49**	**16,15**
Software (I_Soft)	4,03	1,05	0,99	0,30	0,57	0,17	0,54	0,95	4,31	9,07
Computing equipment (I_IT)	2,63	5,80	6,02	4,41	3,67	1,90	1,24	1,46	2,51	3,49
Communication equipment (I_CT)	2,67	3,11	1,23	2,12	3,28	2,57	0,75	3,16	3,67	3,59
Non-ICT	**90,67**	**90,03**	**91,76**	**93,17**	**92,48**	**95,35**	**97,47**	**94,43**	**89,51**	**83,85**
Transport equipment (I_TraEq)	0	9,51	10,02	5,74	11,95	10,12	6,05	8,28	8,43	6,83
Machinery & Equipment (exclu. ICT) (I_Omach)	31,30	18,89	25,81	34,62	33,30	12,57	25,77	17,71	13,83	19,88
Cultivated assets* (I_Cult)	0	2,32	1,77	1,34	5,18	0,43	1,83	0,92	0,47	0,00
Non-residential structures (I_Ocon)	37,56	37,85	36,71	28,64	36,28	31,33	30,72	28,50	30,71	21,41
Residential structures (I_Rstruc)	21,80	15,02	15,89	22,83	5,78	29,50	29,33	39,02	30,86	20,18
Research and development	0,00	1,74	1,30	0,00	0,00	11,41	0,57	0,00	4,36	13,47
Other IPP assets	0,00	4,70	0,26	0,00	0,00	0,00	3,19	0,00	0,86	2,08
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

a.2) GFCF. Average annual growth rates (1995-1996)	Chile	Colombia	Costa Rica	El Salvador	Honduras	México	Perú	Rep. Dominicana	Spain	US
ICT	**15,10**	**2,93**	**5,50**	**1,67**	**8,13**	**11,70**	**9,28**	**20,68**	**9,31**	**8,19**
Software (I_Soft)	25,86	1,37	26,25	9,43	17,08	5,69	9,45	35,89	6,22	7,82
Computing equipment (I_IT)	16,05	3,96	3,39	1,18	8,39	10,55	9,33	42,44	12,96	14,19
Communication equipment (I_CT)	10,70	2,41	13,36	5,21	8,39	13,92	11,81	18,83	14,08	7,44
Non-ICT	**4,28**	**5,31**	**4,95**	**0,68**	**3,76**	**4,24**	**5,41**	**8,28**	**1,52**	**1,64**
Transport equipment (I_TraEq)	0,00	12,10	6,31	5,72	6,83	12,23	9,45	12,59	5,38	5,83
Machinery & Equipment (exclu. ICT) (I_Omach)	7,27	4,43	4,14	0,09	10,79	6,99	6,46	17,75	1,51	2,35
Cultivated assets* (I_Cult)	0,00	6,64	1,14	1,69	6,29	3,93	3,37	2,65	19,84	0,00
Non-residential structures (I_Ocon)	5,10	4,44	5,15	2,81	-0,04	3,30	6,18	9,23	0,05	0,36
Residential structures (I_Rstruc)	1,57	10,69	6,84	-0,15	-1,18	2,45	4,46	10,77	1,74	1,34
Research and development	0,00	3,95	9,95	0,00	0,00	5,91	4,80	0,00	4,59	3,19
Other IPP assets	0,00	1,66	11,05	0,00	0,00	0,00	2,07	0,00	6,81	1,81
Total	**4,79**	**4,94**	**4,92**	**0,66**	**4,13**	**4,43**	**5,67**	**8,38**	**2,20**	**2,32**

UNIVERSIDAD DE SANTIAGO DE CHILE

b) Labor

b.1) Labor share by level of education, 2016 (%)	Chile	Colombia	Costa Rica	El Salvador	Honduras	México	Perú	Rep. Dominicana	Spain	US
High	59,83	45,73	49,55	30,83	18,90	28,69	50,05	45,99	53,65	71,37
Medium	34,64	31,83	30,19	43,75	30,80	55,43	36,92	28,21	21,74	16,57
Low	5,53	22,44	20,26	25,42	50,30	15,88	13,03	25,80	24,61	12,06
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

b.2) Labor Average annual growth rates (1995- 2016)	Chile	Colombia	Costa Rica	El Salvador	Honduras	México	Perú	Rep. Dominicana	Spain	US
High	4,73	2,86	4,37	1,45	10,86	1,90	2,39	3,97	4,30	0,64
Medium	1,60	0,20	2,02	1,69	2,57	2,59	2,05	3,08	3,41	0,28
Low	-3,54	1,51	-0,53	-0,14	2,32	0,48	-2,28	1,80	-1,18	0,06
Total	**2,29**	**1,19**	**2,14**	**1,07**	**2,06**	**1,98**	**1,23**	**2,97**	**1,41**	**0,50**

Main results

- First, as shown in Figure 1, the Latin American countries can be clustered in two groups. The first group consists of Chile and Peru, showing a higher share of knowledge-based GVA, more similar to that of the USA. Colombia, Costa Rica, El Salvador, Mexico, Honduras and the Dominican Republic and El Salvador form the second cluster.
- Second, the US is the undisputed leader according to both the broad and the restrictive approaches. For the remaining countries, the comparison of the results from the two approaches suggests that the restricted approach tends to favor the most developed countries. The US, Spain, Costa Rica and Peru, in this order, occupy the first positions according to the restrictive approach, while under the broad approach, Spain occupies the fifth position after Peru, Costa Rica and El Salvador.

Main results

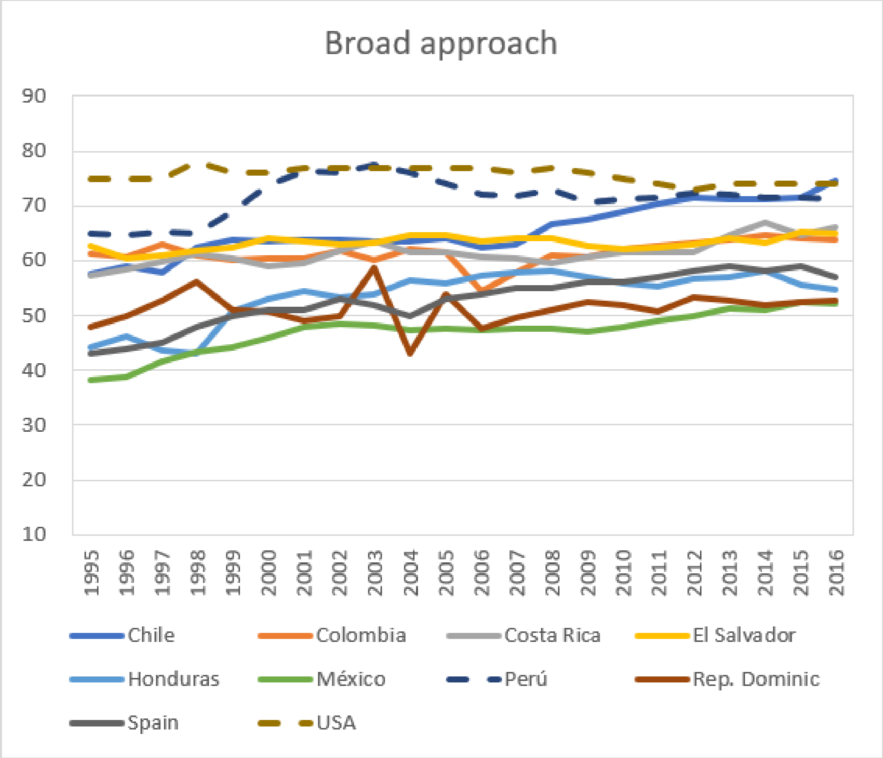
- Third, knowledge-based GVA calculated following the restrictive definition is more dynamic than under the broad definition, meaning that the value generated by the most technological assets and the most educated workers has grown more intensively in all countries.

UNIVERSIDAD DE SANTIAGO DE CHILE

Aggregated results

Knowledge intensity estimates.

Figure 1. Knowledge-based GVA. International comparison, 1995-2016 (percentage over total GVA)



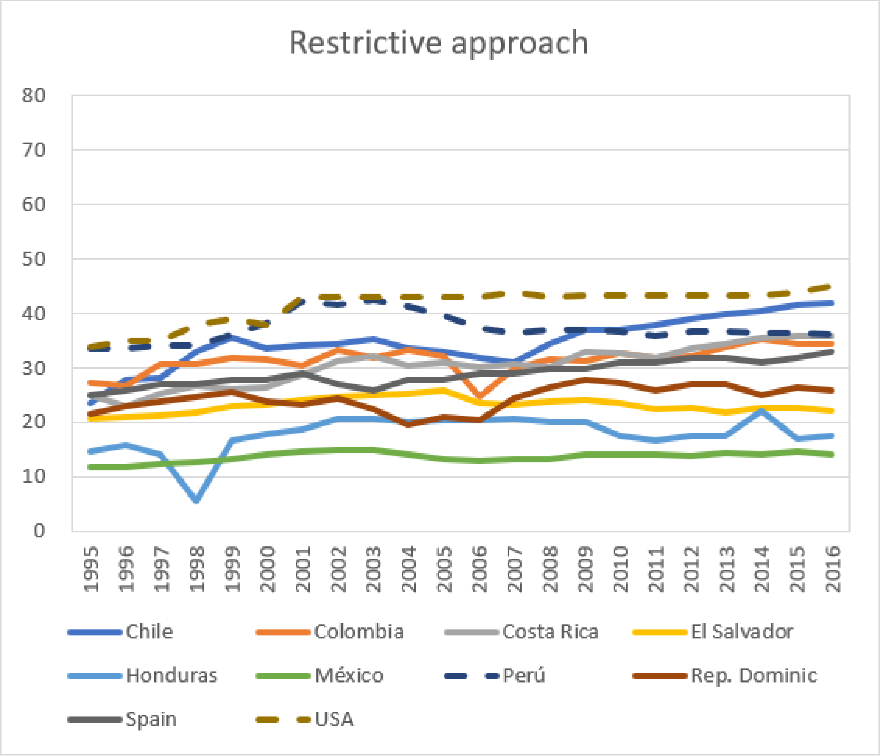


Figure 2. Knowledge-based GVA. International comparison, 1995 and 2016 (percentage over total GVA)

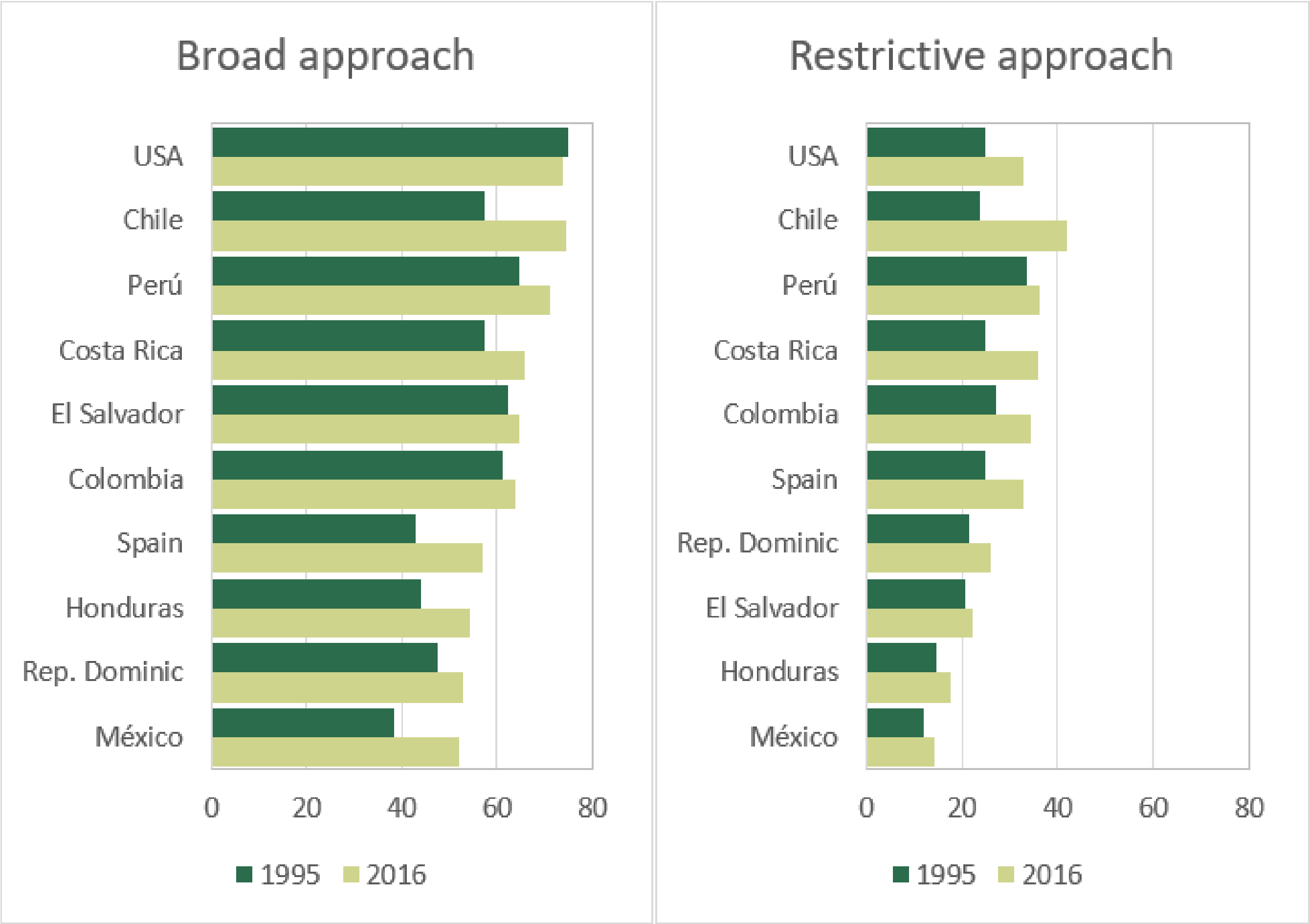
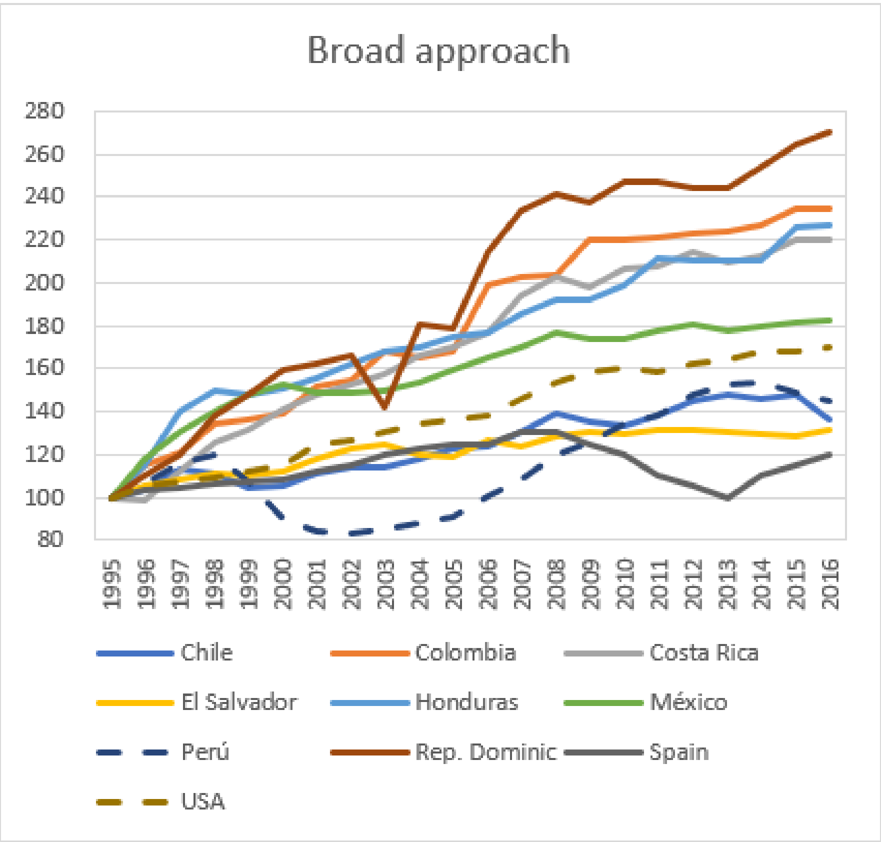


Figure 4. Real non-knowledge GVA. International comparison, 1995-2016 (1995=100)



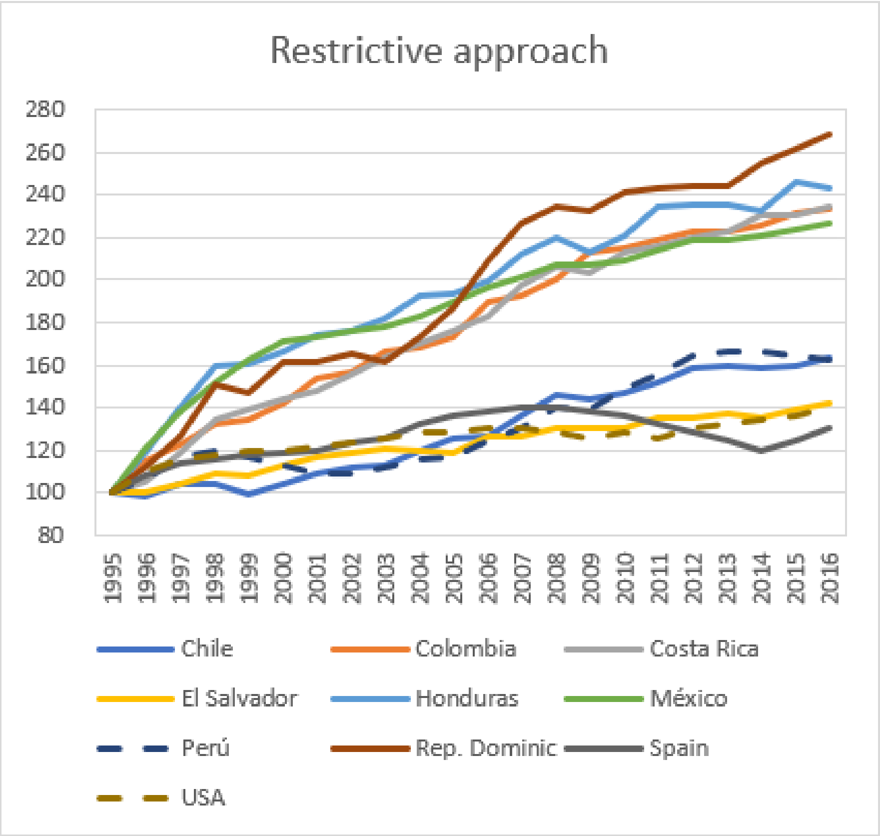
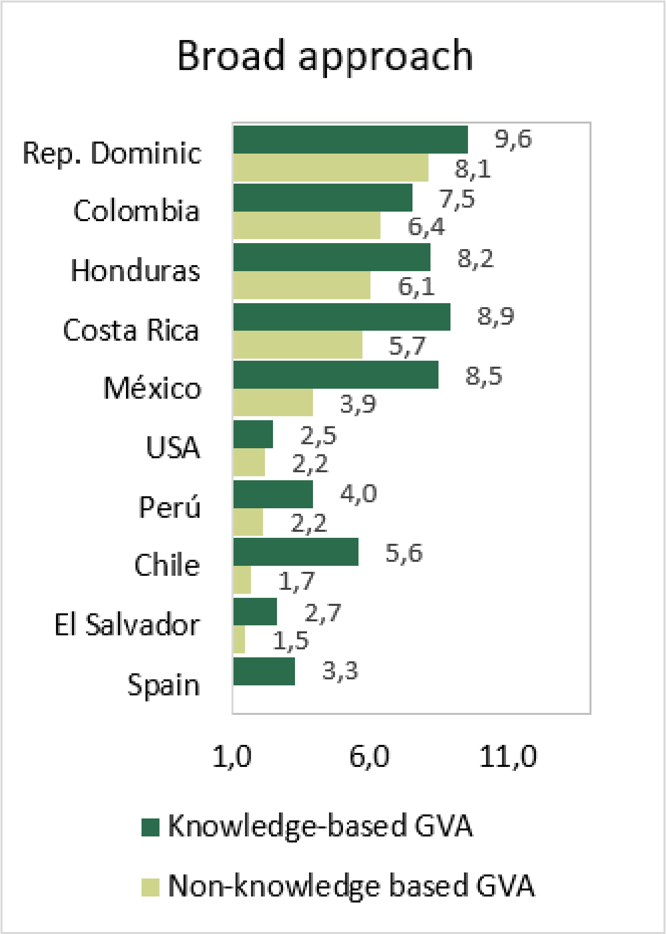
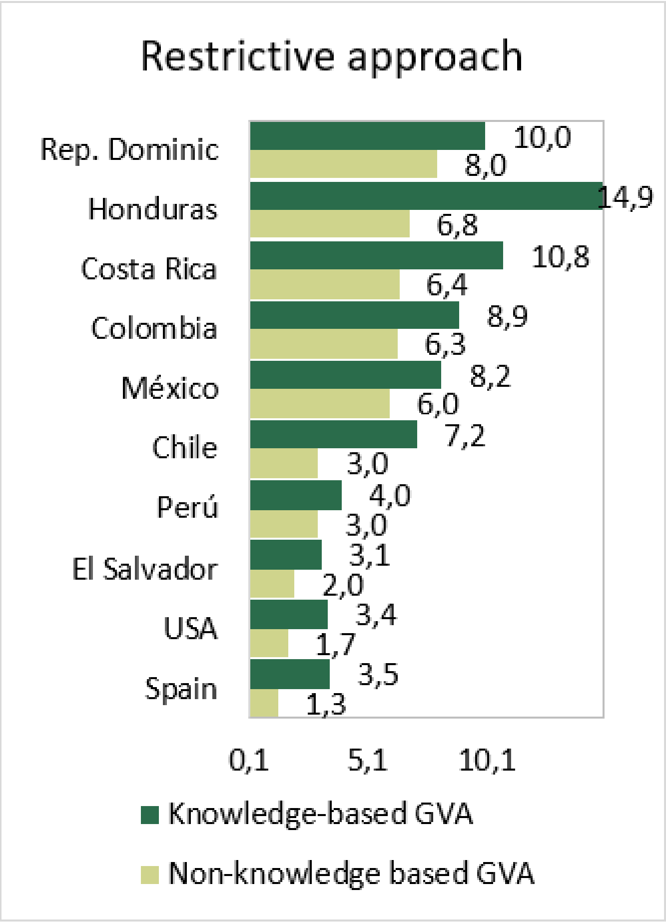


Figure 5. Average growth rate of knowledge and non-knowledge GVA. International comparison, 1995-2016 (percentage)

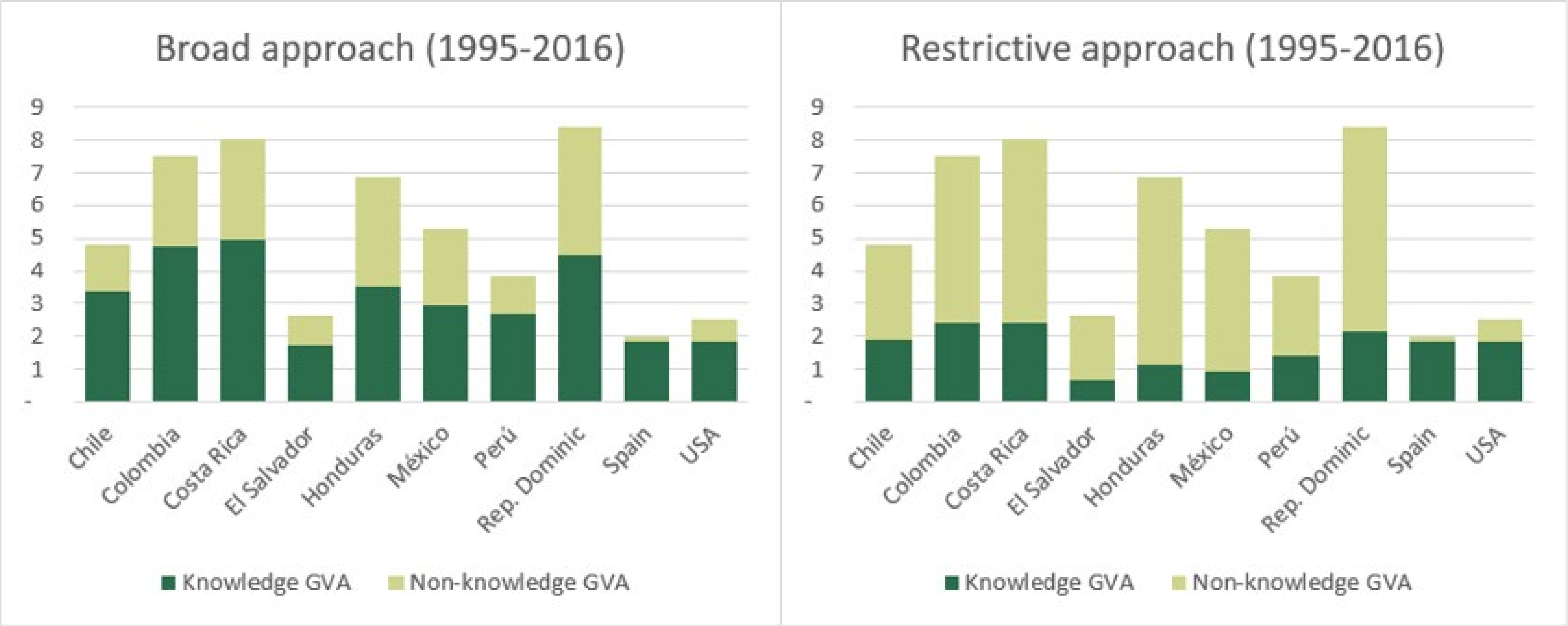




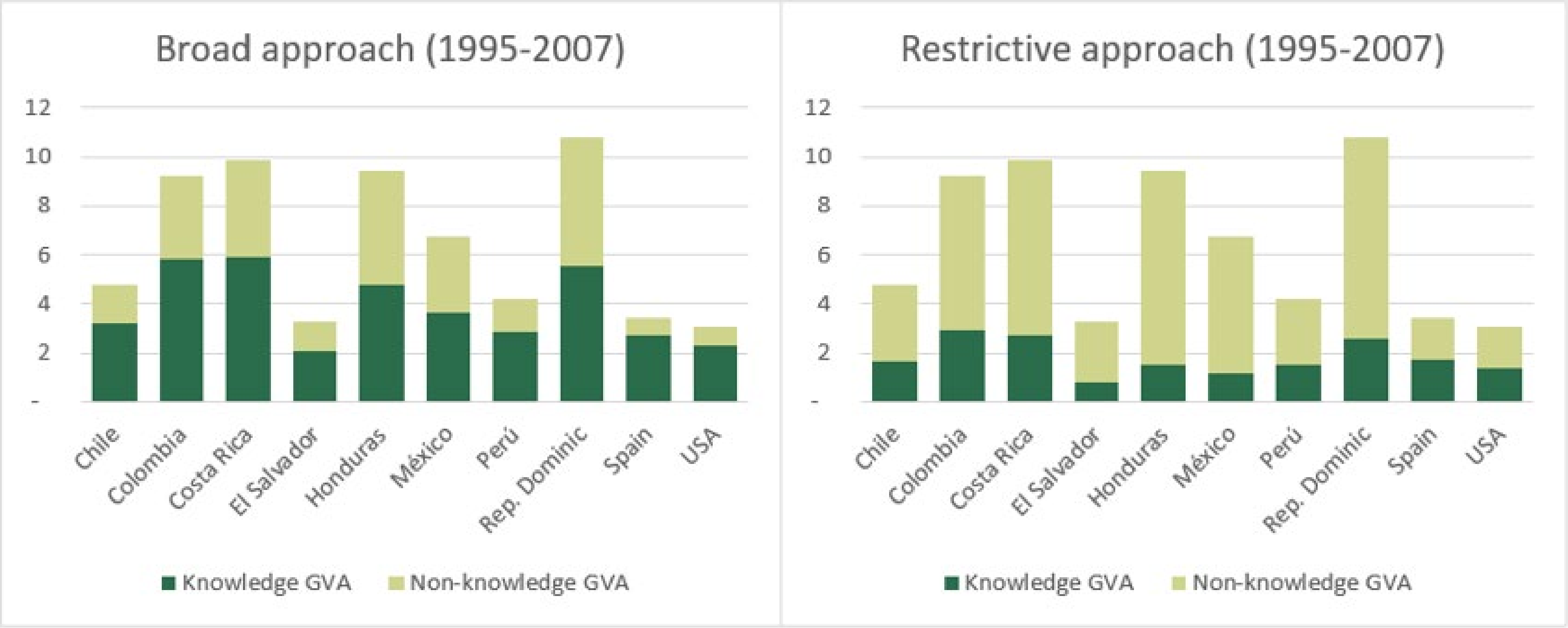
UNIVERSIDAD
DE SANTIAGO
DE CHILE

Figure 6. GVA annual growth rate: knowledge and non-knowledge contribution. International comparison, 1995-2016 (percentage)

a) 1995-2016



b) 1995-2007


Broad approach (1995-2007)
12
10
8
6
4
2
-
Chile
Colombia
Costa Rica
El Salvador
Honduras
México
Perú
Rep. Dominic
Spain
USA
Knowledge GVA
Non-knowledge GVA
Restrictive approach (1995-2007)
12
10
8
6
4
2
-
Chile
Colombia
Costa Rica
El Salvador
Honduras
México
Perú
Rep. Dominic
Spain
USA
Knowledge GVA
Non-knowledge GVA

c) 2007-2016

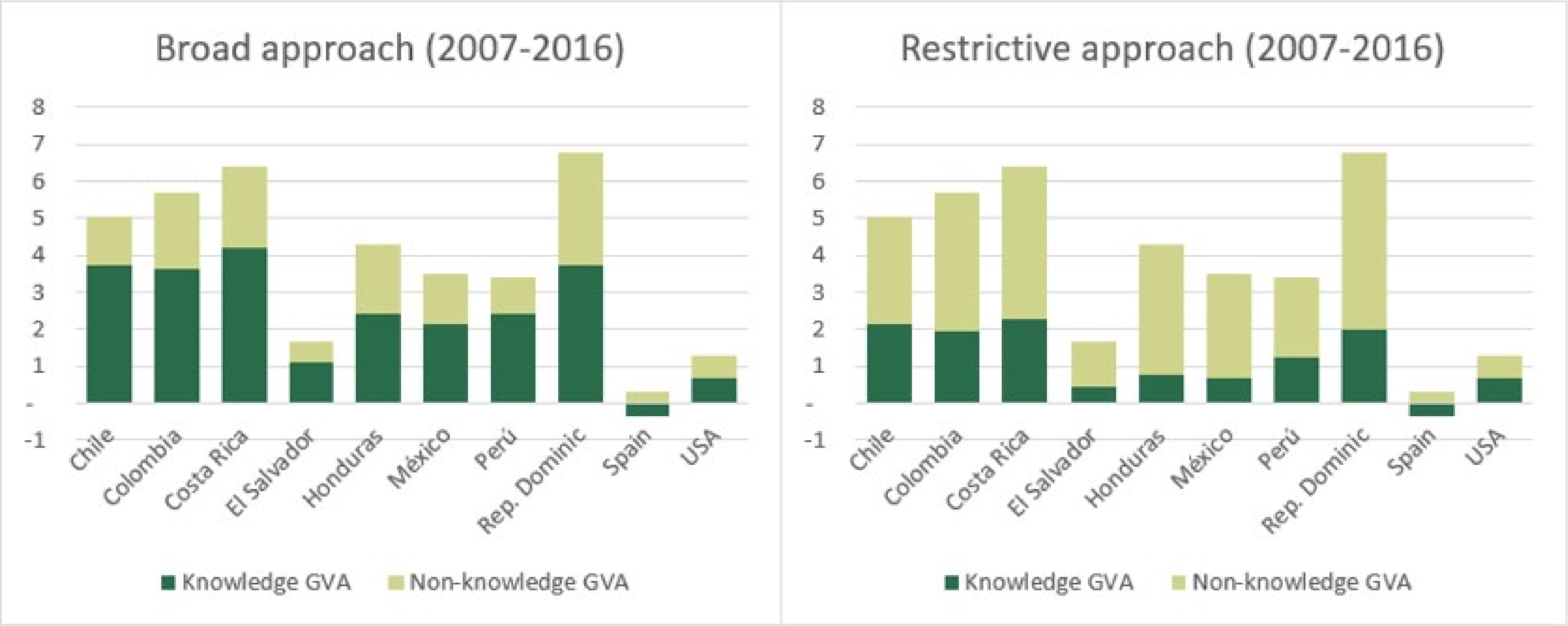

Broad approach (2007-2016)
8
7
6
5
4
3
2
1
-
-1
Chile
Colombia
Costa Rica
El Salvador
Honduras
México
Perú
Rep. Dominic
Spain
USA
Knowledge GVA
Non-knowledge GVA
Restrictive approach (2007-2016)
8
7
6
5
4
3
2
1
-
-1
Chile
Colombia
Costa Rica
El Salvador
Honduras
México
Perú
Rep. Dominic
Spain
USA
Knowledge GVA
Non-knowledge GVA

Table 4. Knowledge and non-knowledge compensation over GVA by source. International comparison, 1995 and 2016 (percentage)

a) 1995

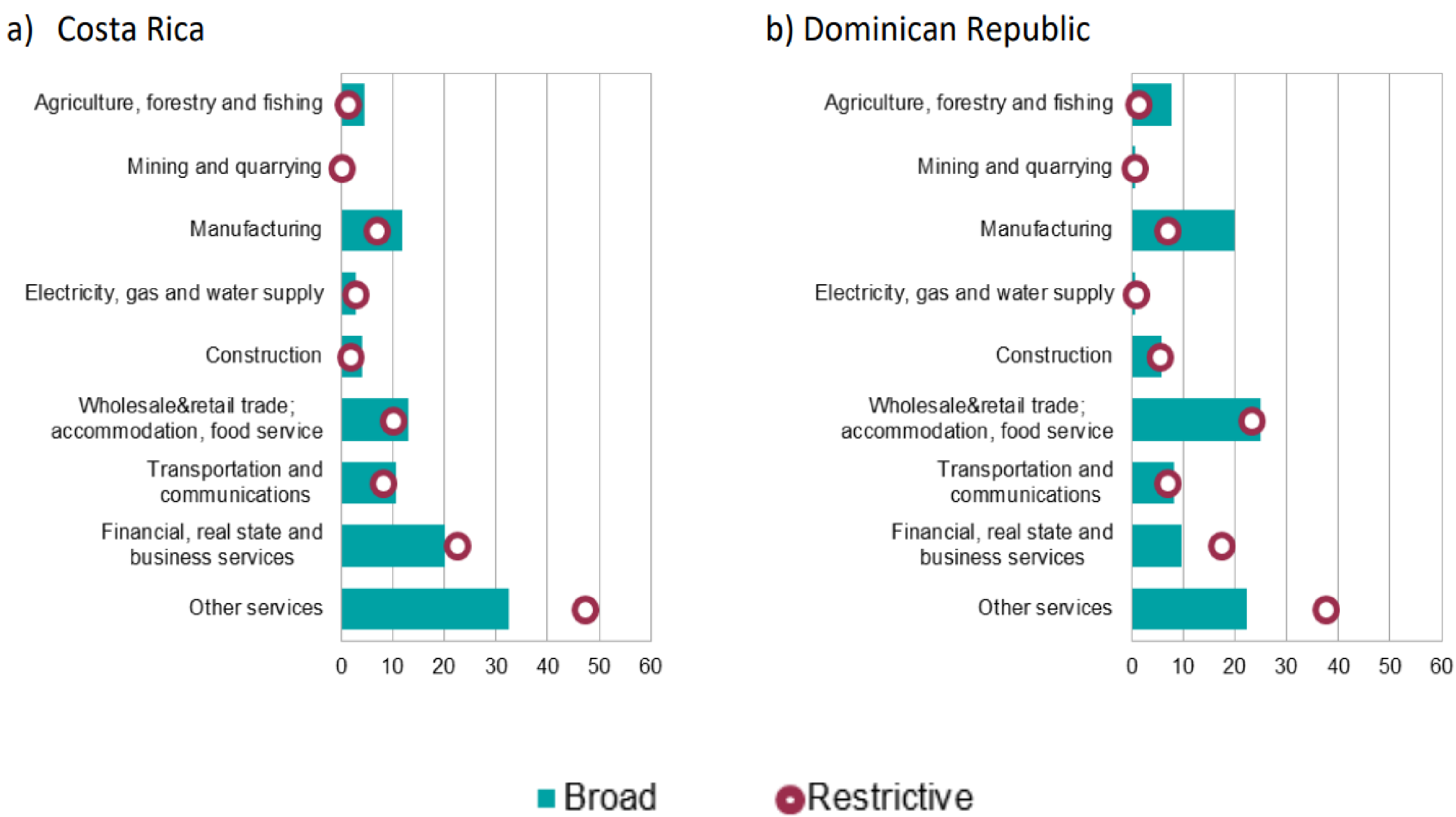
	Chile	Colombia	Costa Rica	El Salvador	Honduras	México	Perú	Rep. Dominic	Spain	USA
ICT capital compensation	0,46	5,47	4,09	1,79	2,52	0,79	1,89	0,26	3,70	4,06
Mach&Equipment capital compensation	6,22	9,21	15,39	15,50	9,96	6,67	6,63	9,78	8,35	11,97
Real estate capital compensation	19,97	24,99	24,38	14,90	24,72	46,27	14,39	32,21	24,28	21,56
Labor compensation. High-skilled	27,82	21,41	18,28	19,43	11,73	13,53	30,54	22,10	21,81	25,84
Labor compensation. Medium-skilled	29,82	24,28	17,44	26,13	19,29	22,64	24,27	16,33	10,25	32,47
Labor compensation. Low-skilled	15,72	14,64	20,41	22,25	31,79	10,10	22,28	19,33	31,61	4,10
Total GVA	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**

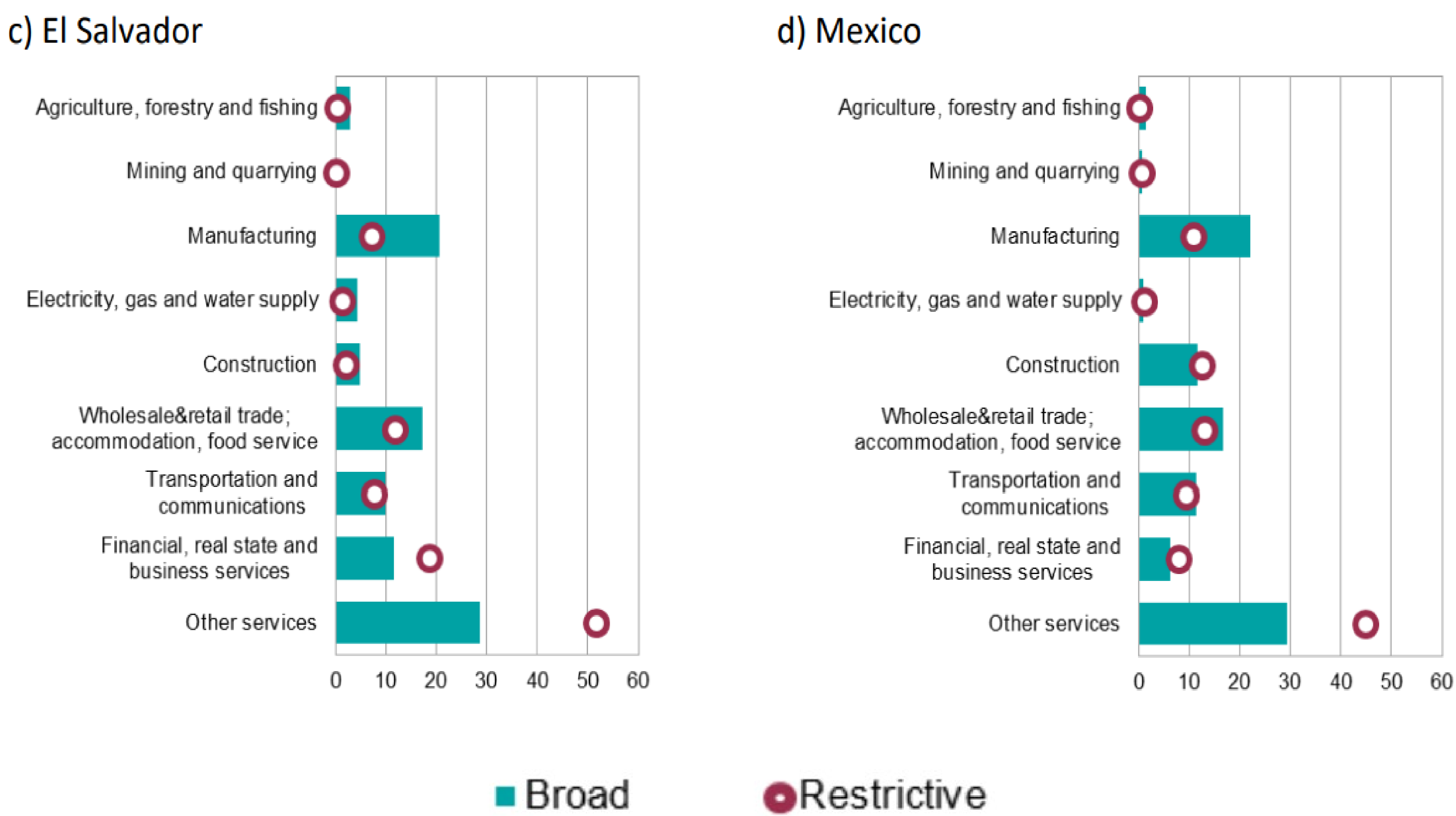
b) 2016

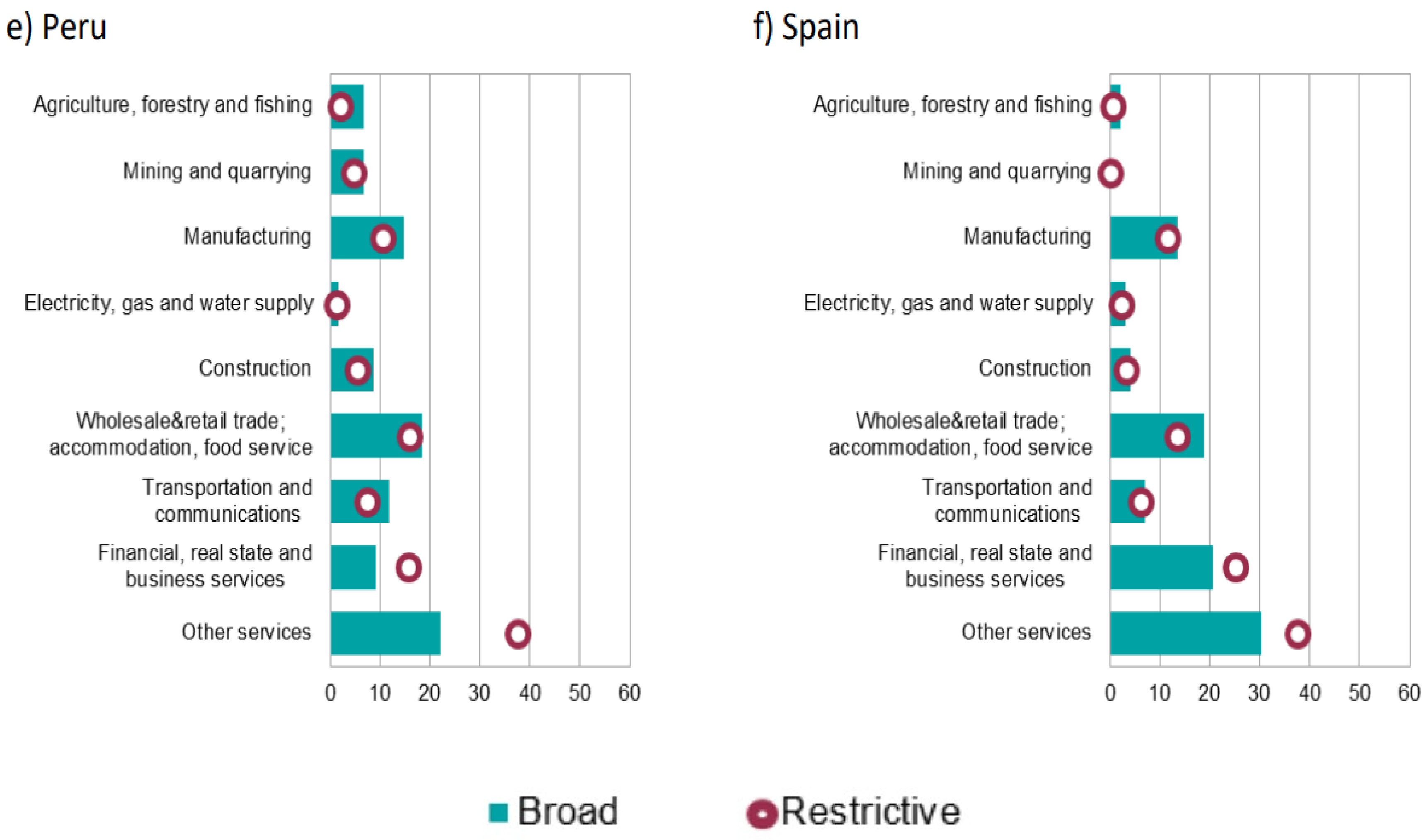
	Chile	Colombia	Costa Rica	El Salvador	Honduras	México	Perú	Rep. Dominic	Spain	USA
ICT capital compensation	3,21	1,95	2,26	1,26	2,63	1,77	3,51	0,96	4,12	4,29
Mach&Equipment capital compensation	7,74	5,93	7,14	9,08	9,64	9,60	10,18	9,32	7,42	10,79
Real estate capital compensation	15,74	17,29	14,70	11,93	5,72	24,51	18,92	26,80	26,83	25,14
Labor compensation. High-skilled	43,86	34,22	37,61	23,97	15,50	18,40	33,73	28,94	31,82	33,87
Labor compensation. Medium-skilled	25,39	23,82	22,91	34,01	25,26	35,54	24,88	17,75	14,00	23,97
Labor compensation. Low-skilled	4,06	16,80	15,38	19,76	41,25	10,18	8,78	16,24	15,81	1,94
Total GVA	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**	**100,00**

UNIVERSIDAD DE SANTIAGO DE CHILE

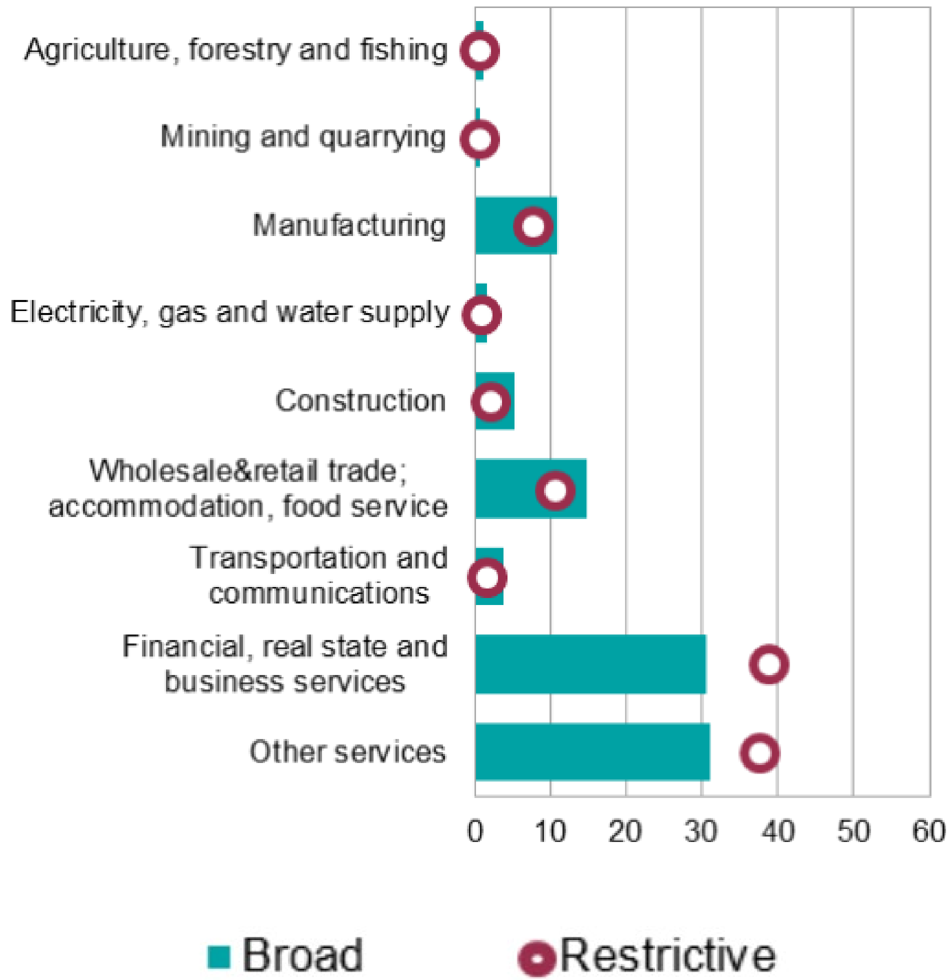
Figure 14. Knowledge-based GVA by industry. Broad and restrictive approach, 2016. Total GVA = 100 (percentage of total knowledge-based GVA)




c) El Salvador
Agriculture, forestry and fishing
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale&retail trade; accommodation, food service
Transportation and communications
Financial, real state and business services
Other services
0
10
20
30
40
50
60
d) Mexico
Agriculture, forestry and fishing
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale&retail trade; accommodation, food service
Transportation and communications
Financial, real state and business services
Other services
0
10
20
30
40
50
60
Broad
Restrictive


e) Peru
Agriculture, forestry and fishing
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale&retail trade; accommodation, food service
Transportation and communications
Financial, real state and business services
Other services
0 10 20 30 40 50 60
f) Spain
Agriculture, forestry and fishing
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale&retail trade; accommodation, food service
Transportation and communications
Financial, real state and business services
Other services
0 10 20 30 40 50 60
Broad
Restrictive

g) US


Agriculture, forestry and fishing
Mining and quarrying
Manufacturing
Electricity, gas and water supply
Construction
Wholesale&retail trade; accommodation, food service
Transportation and communications
Financial, real state and business services
Other services
0
10
20
30
40
50
60
Broad
Restrictive

CONCLUSIONS

- Fourth, this growth was particularly intense in Costa Rica, the Dominican Republic and Peru, compared with more modest growth in El Salvador, Mexico, Spain and the US. Overall, this result suggests that there was some convergence over the period, with the countries ranked lowest in 1995 growing faster than the leaders.
- Fifth, the behavior revealed in the US and Spain during the great recession years indicates that the non-knowledge part of the economy is more vulnerable to difficult times than its knowledge counterpart. Or put another way, the knowledge-based economy is more resilient to the consequences of negative shocks.

CONCLUSIONS

- Sixth, when our results are compared with other traditional measures, important differences arise that can be explained by the consideration of more than one single factor (as in the case of R&D intensity), by the fact that our objective is to measure the use of knowledge by the economic activities and not only knowledge generation, and by the consideration of the remunerations for the different factors of production in addition to their physical or absolute quantities.
- Seventh, in almost all the countries, knowledge-intensive labor contributed more to GVA growth than knowledge-intensive capital.

CONCLUSIONS

- Eighth, from the sectoral perspective, in almost all countries, the *Other services* (which includes Public administration, Education, Health, Social services, Arts, entertainment and recreation and other services) sector absorbs the highest share of the knowledge economy. The second most important sector in most developed countries is *Financial, real estate and business services*. *Manufacturing* takes second position in El Salvador and Mexico, and *Wholesale & retail trade, accommodation and food service* in Peru and the Dominican Republic. These four sectors absorb the highest share of the total knowledge economy, regardless of the approach, while the other five sectors have a much smaller share, especially *Agriculture, Mining and quarrying*, and *Electricity, gas and water supply*.
- Ninth, broadly speaking, it seems that the more developed a country is, the more evenly the knowledge economy is spread across all the sectors of the economy. Spain and the United States, and also Costa Rica and Peru, illustrate this observation.

CONCLUSIONS

- Finally, we should emphasize the usefulness of our conclusions in designing public policies to improve the workings of a knowledge-based economy and its growth. New policies could be defined to facilitate the penetration of knowledge-intensive assets (both capital and labor) in Latin American economic sectors, especially those with lower knowledge intensity. The comparison with the United States and Spain is a valuable benchmark as it offers two reference points to take into consideration.