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Does government financial support decrease the inefficiency of public universities? A decomposition approach

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ABSTRACT

This study contributes to the literature by considering for the first time the link between government financial support and the efficiency of public universities in Vietnam. Using the Färe-Primont index decomposition approach, the study shows that the decline in the aggregate efficiency of the universities was driven by a decline in technical efficiency and in residual mix efficiency. Our analysis further reveals that while an input-based government funding system is found to decrease scale efficiency, an increase in the investment ratio for academic and research activities promotes the aggregate, allocative efficiency of public universities.

1. Introduction

The government provides funding to public universities on an annual basis to support their academic activities. The difference between the total budget allotted for annual expenses and the actual total tuition revenue is used to fund public universities. Various theoretical perspectives account for the linkage between government support and university performance. As a result of government support, on the one hand, additional financing may become available, allowing institutions to expand their resources in areas where they are lacking. Such support enables universities to boost their research and development (R&D) spending and so improve their performance. Furthermore, when the government guarantees long-term aid for universities, the effectiveness of government funding can curb the threat of "academic capitalism" (Strehl et al., 2007). Academic capitalism reflects the tendency of the university system to focus on applied research activities driven by the market (business or industry), setting aside basic scientific research which does not

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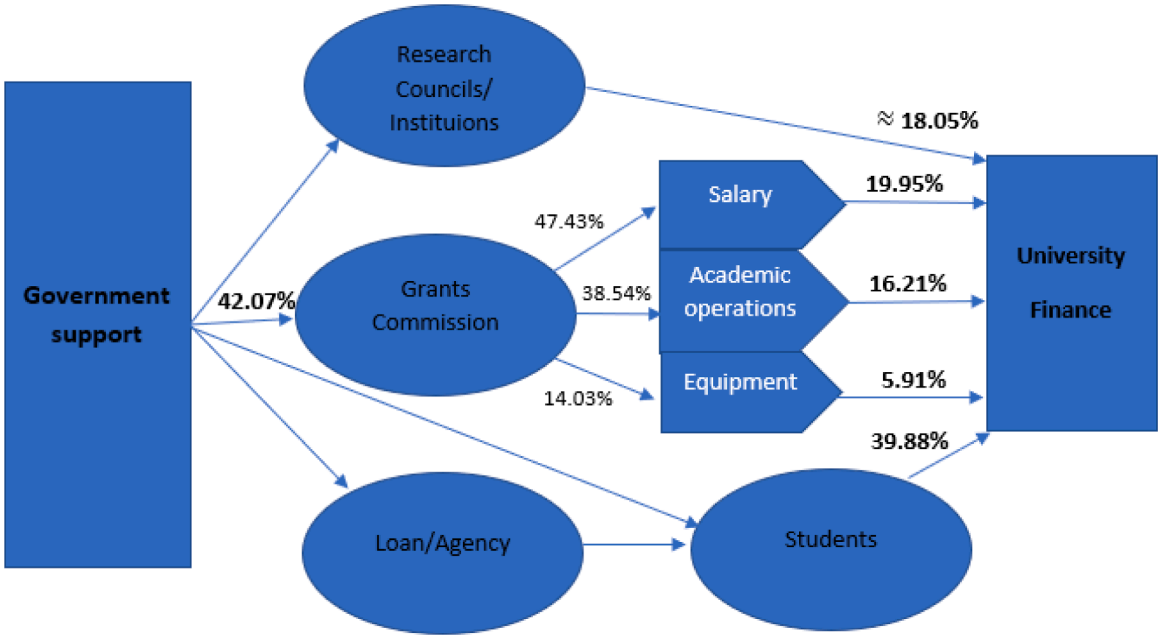

Fig. 1. Vietnam's Public University Finances: Cost recovery in 2016

guarantee a financial return in the short term, and therefore limiting efficiency and sustainable growth in the long term. More seriously, in developing countries, inadequate operational revenue is the reason why research activity cannot develop strongly. Moreover, a government funding program facilitates state oversight influencing the higher education system by enforcing compliance with domestic commitments and the needs of domestic labor (instead of domination by foreign entities) in both teaching and research activities (see also Hillman et al., 2015; Hillman et al., 2014).

On the other hand, the theory of public financial management (e.g., Adikara, 2015) shows that with government incentives focusing on short-term instead of long-term quality, financial aid harms the performance of institutions of higher education. Universities will change their strategy, embracing the proposed criteria to gain favor with central government, shown in rapid upgrading (increasing enrollments, new faculty, new training programs). In this way, government supportslimit diversity in teaching and research output, increase quantity at the cost of quality, and eliminate research programs and curricula not included in the resource allocation criteria (basic research or long-term university purposes). In addition, government subsidies awarded on the basis of social networks or political connections are not beneficial for performance because of distortion in the efficient allocation of resources among universities, and hence may result in the slow growth of a university and its efficiency (e.g., Vu and Ly, 2019; Vu and Tran, 2021).

Employing various theoretical arguments, several studies consider sources of funding for university education (e.g., Liu et al., 2021), and others assess the importance of schooling in a person's financial decision-making patience. (e.g., Barua et al., 2018; Park, 2019). However, no study considers the influence of government financial support on university performance.

Government funding for Vietnam's public universities (VPUs) can be described as an input-based system (Ziderman and Albrecht, 2013; World Bank, 2020), whereby the amount of aid depends largely on input indicators, such as the number of students and lecturers and infrastructure, rather than on output criteria. Although several studies consider several aspects of university efficiency (e.g., Tran and Villano, 2017), a lack of information about how universities spend the government funding they receive limits the government's ability to develop appropriate policies. We make two contributions to fill this gap in the current literature. First, our study uses the Färe-Primont (FP) index decomposition approach, which enables us to evaluate the varying effectiveness of the education system and determine the main drivers of VPU inefficiency in Vietnam. Secondly, this study is one of the first attempts to consider the impact of government funding on aggregate efficiency and its decompositions. The conventional approach that fails to address the endogeneity issue and unobserved factors may lead to biased results. Our endogeneity-corrected estimates provide solid evidence of the effect of government support on university performance. Our results provide novel findings that can help policy makers develop better strategies for providing state funding for the sustainable development of public universities.

2. The context of Vietnam's government financial support for university

The way government supports universities in Vietnam takes two forms: (i) direct funding from the state budget for a university's investment and recurring expenditures, and (ii) indirect forms of assistance through preferential credit loans for students (e.g., decree 116/2020/ND-CP) and aid for the activities of research organizations, centers, and institutions. The allocation of direct government funding to public universities can be viewed as an input-based funding regime (Ziderman and Albrecht, 2013; World Bank, 2020), whereby the size of a grant depends largely on input indicators (e.g., the number of students and lecturers) instead of performance

criteria. Public universities submit a budget request according to Circular 137/2017/TT-BTC, which has budget approval criteria related to the number of students, lecturers, and curricular and classroom facilities, and grant size is controlled by the Ministry of Education and Training (MOET) (Hayden and Thiep, 2010).

Government funding is used directly for internal university expenditures, including (i) recurrent expenditures, such as for salaries for staff and lecturers, and administrative expenses; (ii) academic spending, such as research activities and the organization of seminars; and (iii) expenditure on equipment (e.g., new purchases, the repair and maintenance of equipment). The sources of revenue for public universities in 2016 are calculated as shown in Fig. 1, showing that most government funds are used for salary payments and academic activities (nearly 86%). How will this financial structure affect the efficiency and its decompositions of public universities? The following section provides evidence to clarify the matter.

Source: Calculation of authors[1]

This study considers the role of government supports in the efficiency of public universities in Vietnam stemming from several notable points: (i) The government financial support system provides a typical example of an input-based funding approach. (ii) The performance of public universities and the size of grants made to them are characterized by independent, identically distributed (i.i.d.) random variables. Large fluctuations make it possible to determine a causality nexus. (iii) Vietnam can be seen as a representative Southeast Asian country aiming for sustainable goals for its higher education system.

First, Vietnam's input-based funding system comes under long-standing influence, first from Confucianism, then from the Soviet ideology of the 1950s-80s, especially the latter's line-management control approach. Accordingly, on the one hand, MOET strictly controls enrolment quotas, lecture quality, the framework for curricula, the ceiling for tuition fees, and expenditure norms for public universities (Hayden and Thiep, 2010). On the other hand, they determine block grants and scholarship allocations according to their input criteria. Approval criteria and block-grant distribution mechanisms are constantly improved, making Vietnam an excellent example of input-based funding as compared with performance-based funding.

Second, MOET's strict control of the organizational structure and operation (e.g., Circular No. 10/2020/TT-BGDDT[2] and Decree 69/2017/ND-CP[3]) of public universities also guarantee the i.i.d random variables of public compared to private universities. Furthermore, during the study period (2013-2016), the government encouraged financial autonomy in the public sector (see Decision 303/QD-TTG[4] and Decision 1454/QD-TTG[5]), indirectly creating considerable variations in grant size. The properties mentioned above facilitate that it is necessary to consider a cause-and-effect relationship between financial support and the performance of public universities.

3. Data and methodology

3.1. Data source

The data used for this research has been collected directly from two main sources. The first provides data for 70 public universities provided by the Ministry of Education and Training (MOET) for 2013-2016. The many indexes in this source include input/output indicators, owners, and governing bodies, etc., to calculate a university's efficiency and its decompositions. The second data source reports government funds provided by the Ministry of Planning and Investment (MPI) for the same period. All nominal financial aid has been adjusted for the education price index.

3.2 Methodology

To measure aggregate efficiency and its decompositions in finance studies, the Färe-Primont index decomposition approach is commonly applied (e.g., Al-Khasawneh et al., 2020; Feng and Wang, 2018). Specifically, according to previous studies (e.g., Tran and Renato, 2017), and based on the input-oriented approach, TFP and its university components are calculated as follows: [6]

$$\begin{aligned} \underbrace{TFPE}_{Performance\ efficiency} &= \underbrace{TFP}_{Total\ Factor\ Productivity} : \underbrace{TFP*}_{Maximum\ of\ TFP\ given\ period\ t} \\ &= \underbrace{ITE}_{Input-oriented\ technical\ efficiency} \times \underbrace{ISME}_{Input-oriented\ scale-mixed\ efficiency} \\ &= ITE \times \underbrace{ISE}_{Input-oriented\ scale\ efficiency} \times \underbrace{RME}_{Residual\ of\ mixed\ efficiency} \end{aligned} \quad (1)$$

[1] The analytical framework is adapted from Ziderman & Albrecht (2013).
[2] "Promulgating organizational and operational regulation of regional parent universities and constituent higher education institutions thereof."
[3] Stipulates the functions, tasks, powers and organizational structure of the Ministry of Education and Training.
[4] Providing a specific financial mechanism for Viet Duc University.
[5] Providing a specific financial mechanism for Vietnam-Japan University.
[6] Details of calculations of aggregate efficiency and its decompositions, please see the Appendix 2

Table 1
TFP and its decompositions in Vietnam's public universities in the 2013-2016 period.

	TFP	TFP*	TFPE	ITE	ISME	ISE	RME
2013	0.7521	3.6116	0.2082	0.8188	0.2543	0.8952	0.2841
2014	0.5536	3.6116	0.1533	0.7413	0.2068	0.9059	0.2282
2015	0.5096	3.6116	0.1411	0.7447	0.1895	0.9074	0.2088
2016	0.6022	3.6116	0.1667	0.7669	0.2174	0.9417	0.2309
Change	dTFP	dTECH	dTFPE	dITE	dISME	dISE	dRME
16/13	0.8007	1.0000	0.8007	0.9366	0.8549	1.0519	0.8127
14/13	0.7361	1.0000	0.7363	0.9053	0.8132	1.0120	0.8032
15/14	0.9205	1.0000	0.9204	1.0046	0.9163	1.0017	0.9150
16/15	1.1817	1.0000	1.1814	1.0298	1.1472	1.0378	1.1058
On average (%)	-5.41	0.00	-5.41	-1.62	-3.84	1.27	-5.05

Table 2
The impact of government funding on the performance of VPUs.

VARIABLES	Aggregated efficiency			ITE		
	FE	GMM	GMM	FE	GMM	GMM
	(1)	(2)	(3)	(4)	(5)	(6)
Total government financial support	-0.0134	0.0221		-0.0246	0.0441	
	(0.015)	(0.024)		(0.016)	(0.029)	
Salary support			0.0256			-0.0334
			(0.044)			(0.064)
Research support			-0.0266			0.1336
			(0.064)			(0.121)
Equipment support			-0.0202			-0.0635
			(0.049)			(0.124)
Land in log	-0.0420	0.0796	-0.0006	-0.0440	0.2237	-0.0405
	(0.041)	(0.066)	(0.020)	(0.051)	(0.149)	(0.047)
University principal		0.0114	0.0723		0.1357	0.1214+
		(0.116)	(0.049)		(0.165)	(0.068)
Age in log	-0.1073	-0.0577**,*	-0.0285*	-0.2165	-0.1028	0.0162
	(0.152)	(0.029)	(0.014)	(0.197)	(0.084)	(0.022)
Constant	1.2717+	-0.7392	0.3009	2.3746*	-1.9612	1.1387*
	(0.754)	(0.902)	(0.211)	(0.977)	(1.702)	(0.463)
Observations	275	275	276	275	275	276
R-squared	0.066			0.037		
Number of panels	69	69	69	69	69	69
Durbin–Wu–Hausman test for endogeneity of regressors (P value)		0.003	0.01		0.01	0.01
Hansen–J test of over-identification (P value)		0.1	0.264		0.263	0.494
Diff-in-Hansen tests of exogeneity (p-value)		0.436	0.396		0.410	0.487

Notes: Robust standard errors in parentheses. Time dummies are also taken into account by the model.
** $p < 0.01$,
* $p < 0.05$,
+ $p < 0.1$. University age and year dummies are deemed exogenous by Wintoki et al., and Netter (2012).

In further analysis, to assess the role of government spending on the efficiency and its decompositions of public universities in Vietnam, a reduced-form model is specified as below:

$$Y_{it} = \beta_1 + \beta_2 * GV_{it} + \beta_3 * X_{it} + year\ dummies + \mu_i + v_{it} \quad (2)$$

where Y_{it} is the aggregate efficiency or its decompositions of university i in year t; government support (GV) is the main variable of interest in the model. In this study, we measure government support as a set of variables. First, it is measured as the total value of government financial support, and the type of support. In addition, the type of government financial support is calculated in terms of three rates. Rate 1 is calculated as the ratio between salary support and total financial support, Rate 2 is calculated as the ratio between research support and total financial support, and Rate 3 is calculated as the ratio between equipment support and total financial support.

Z is a vector of university-level explanatory variables used in the model, following previous studies (e.g., land size, age of the university, university principal or president). μ_i represents time-invariant unobserved firm characteristics. These time-specific effects are captured by year dummy variables; and ε_{it} is the classical error term. One of the biggest challenges in empirical studies is how to deal with the endogeneity of government support variables. Endogeneity results in biased and inconsistent estimations. When all independent variables are deemed to be endogenous, in practice the standard instrumental variable (IV) technique is hard to apply to reduce the risk of simultaneity. Consequently, Blundell and Bond's BB system GMM estimator was used in this study. They assert that if

Table 3
The impact of government funding on the performance of VPUs.

VARIABLES	ISE			RME		
	FE	GMM	GMM	FE	GMM	GMM
	(1)	(2)	(3)	(4)	(5)	(6)
Total financial support	-0.0174**	-0.0116*		-0.0007	0.0104	
	(0.006)	(0.005)		(0.015)	(0.026)	
Salary support			-0.0495+			0.0306
			(0.027)			(0.057)
Research support			0.0062			-0.0468
			(0.063)			(0.073)
Equipment support			-0.0273			0.0395
			(0.072)			(0.112)
Land in log	0.0743*	-0.0013	0.0170	-0.0513	0.0433	0.0065
	(0.035)	(0.013)	(0.026)	(0.035)	(0.046)	(0.017)
University principal		-0.0391**	0.0047		-0.0218	0.0212
		(0.014)	(0.030)		(0.079)	(0.057)
Age in log	-0.1600+	0.0164+	0.0087	-0.0748	-0.0406+	-0.0280*
	(0.084)	(0.009)	(0.013)	(0.139)	(0.022)	(0.014)
Constant	0.7927+	1.0599**	0.7110**	1.1999+	-0.1081	0.3681*
	(0.454)	(0.171)	(0.259)	(0.629)	(0.650)	(0.168)
Observations	275	275	276	275	275	276
R-squared	0.069			0.054		
Number of panels	69	69	69	69	69	69
Durbin–Wu–Hausman test for endogeneity of regressors (P value)		0.002	0.00		0.04	0.003
Hansen–J test of over-identification (P value)		0.1	0.1		0.545	0.235
Diff-in-Hansen tests of exogeneity (p-value)		0.234	0.135		0.616	0.608

Notes: Robust standard errors in parentheses. Time dummies are also taken into account by the model.
** $p < 0.01$,
* $p < 0.05$,
+ $p < 0.1$. University age and year dummies are deemed exogenous by Wintoki et al. (2012).

Table 4
The impact of the financial support framework on the TFP and its decompositions.

VARIABLES	Aggregate efficiency		ITE		ISE		RME	
	FE	GMM	FE	GMM	FE	GMM	FE	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rate1	0.0292	0.1188	-0.0388	0.1876	-0.1238+	-0.0805	0.1181	0.0299
	(0.119)	(0.145)	(0.142)	(0.205)	(0.067)	(0.072)	(0.138)	(0.146)
Rate2	0.0546**	0.0493**	-0.0074	0.0276	0.0267**	0.0071	0.0530**	0.0345**
	(0.016)	(0.010)	(0.023)	(0.022)	(0.007)	(0.008)	(0.016)	(0.010)
Rate3	-0.0363	0.0110	0.1211	0.1835	-0.0970**	-0.0804	-0.0336	-0.0629
	(0.064)	(0.083)	(0.082)	(0.172)	(0.031)	(0.052)	(0.074)	(0.079)
Land in log	-0.0439	0.0469	-0.0409	0.0244	0.0700+	0.0140	-0.0526	0.0406
	(0.042)	(0.029)	(0.051)	(0.039)	(0.037)	(0.013)	(0.035)	(0.027)
Age in log	-0.1805	-0.0321+	-0.1910	0.0033	-0.1960*	0.0061	-0.1469	-0.0255
	(0.141)	(0.017)	(0.211)	(0.021)	(0.084)	(0.011)	(0.119)	(0.016)
University principal		-0.0169		0.1770*		-0.0543+		-0.1113+
		(0.056)		(0.081)		(0.030)		(0.063)
Constant	1.3582+	-0.2561	1.9871+	0.3633	0.8119+	0.7821**	1.3829*	0.0025
	(0.731)	(0.345)	(1.019)	(0.451)	(0.464)	(0.139)	(0.570)	(0.345)
Observations	275	275	275	275	275	275	275	275
R-squared	0.075		0.037		0.077		0.068	
Number of panels	69	69	69	69	69	69	69	69
Durbin–Wu–Hausman test for endogeneity of regressors (P value)		0.03		0.004		0.005		0.001
Hansen–J test of over-identification (P value)		0.264		0.494		0.1		0.235
Diff-in-Hansen tests of exogeneity (p-value		0.396		0.487		0.135		0.608

Notes: Robust standard errors in parentheses. Time dummies are also taken into account by the model.
** $p < 0.01$,
* $p < 0.05$,
+ $p < 0.1$. University age and year dummies are deemed exogenous by Wintoki et al. (2012).

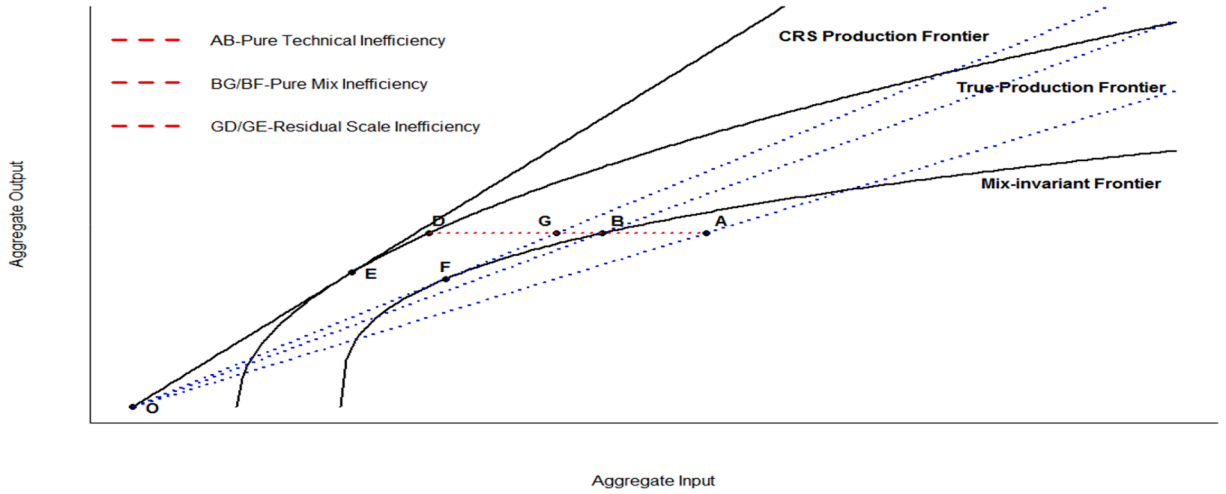

Fig. 2. Description of aggregate efficiency and its decompositions.

T is fixed, this strategy can address the inconsistency caused by endogenous explanatory variables in dynamic models.

4. Empirical results and discussion

Table 1 shows that total factor productivity (TFP), technical efficiency (ITE) and allocative efficiency (RME) declined annually from 2013-2016 by an average of 5.41%, 1.62%, and 5.05%, respectively. Among TFP's components, the most driven factor is scale efficiency (ISE) that ranges from 89.52% to 94.17%, indicating that public university systems can improve by 5.83-10.48% through streamlining current operations (e.g., reducing inefficiency in the hiring of faculty and staff). The stagnation of TFP comes from residual mix efficiency (RME), with only about 20.88-23.09%, revealing poor resource allocation in the public university sector. The incomplete, inadequate financial mechanism records are a major barrier to improving output quality. The results imply that improvement in the efficiency of resource allocation at public universities could be nearly 80% compared to current levels.

Source: Authors

This study further considers the role played by government financial support in university efficiency and its decompositions. The effect of government support on university performance and efficiency (Table 2, column 1) is statistically insignificant. The results may be biased, however, due to the model's failure to account for endogeneity. The validity of system GMM estimation was determined using the Hansen-J test for overidentification. The outcome is displayed in the last row of Table 2. The p-values for the Hansen-J test are 0.1, 0.264, 0.263 and 0.49, respectively. The validity of the GMM system instrumental variables used in this study is supported by these findings. An exogeneity test on a selection of our instruments yielded p-values of 0.53 and 0.612, respectively, as shown in Table 3. Based on these findings, the hypothesis of the exogeneity of the additional subset of instruments included in the GMM system estimations cannot be ruled out. The results in columns 2 and 3 of Table 2 show that government support and the types of government support have little effect on aggregate efficiency. The results accord with public management theory, that an input-based funding mechanism limits diversity in teaching and research output and promotes quantity at the expense of quality. This mechanism also eliminates research programs and curricula that do not meet resource allocation criteria. Thus, the efficiency of universities does not improve.

Regarding the role of government support on each component of efficiency, Table 3 shows that while government funding does not affect technical or allocative efficiency, it reduces scale efficiency (column 3). Specifically, for every hundred billion dong in state grants, there will be an effective reduction of 0.012 scale points. This finding is consistent with Tran and Villano (2017), who found that public university total efficiency decreased in 2013/14. However, these researchers are unaware of economies of scale at Vietnamese universities. Our result supports the argument that in input-based funding systems, government aid will spur public universities to upgrade size instead of improving the quality of their practice in higher education. Ziderman and Albrecht (2013) also assert that input-based funding reduces the effectiveness of universities by discouraging the diversification of sources of revenue, creative programs and connectivity with the demands of the market.

To provide additional insight into the linkage between government support and university performance, this study further examines the financial structure of government support and the way it affects the performance of public universities. The results are presented in Table 4 below.

The results in Table 4 show that a rise in funding for academic operations, such as investment in research and improving the quality of lecturers, plays an important role in improvements in efficiency in general and allocative efficiency in particular. In the Vietnamese context, this shows that government funding helps to reduce financial pressure on public universities, whose resources are already curtailed by regulations constraining tuition fees. Increased government funding allows public universities to be more flexible in allocating resources, balancing research and teaching activities, changing faculty structures and improving the efficiency of the

university.

5. Conclusion and policy implication

Using the panel dataset of public universities from 2013-2016, the study reveals a declining trend in the efficiency of Vietnam's public universities by an average of about 5.41%. The study also shows that Vietnam's funding system, not based on any performance criteria, has spurred public universities to increase their recruitment of students and lecturers and to expand training programs instead of concentrating on quality. As a consequence, efficiency is reduced by increasing quantity, driven by demand and need, rather than by quality. This situation highlights the need for appropriate policy to replace the government's current support scheme based on inputs with results-based funding, as well as to promote the financial autonomy of public universities.

The study also reveals that increased government funding for academic operations, such as investment in research and improvement in the quality of lecturers, promotes flexibility in the use of resources, dividing them between research and teaching activities, and thereby advancing allocative and aggregate efficiency. The findings suggest that government financial support remains necessary but in view of budget constraints, the government should prioritize the promotion of academic activities. This approach, as a result, would improve the efficiency of public universities.

Appendices

Declaration of Competing Interest

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare absence of conflicting interests with the funders.

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Appendix 1. Input and output data for evaluating the effectiveness of VPUs

		unit	2013 mean	2014 mean	2015 mean	2016 mean
Input	PhD lecturers	person	104.07	115.17	128.26	139.46
	Master's degree lecturers	person	277.07	289.77	299.43	301.96
	Administrative staff	person	190.91	192.11	192.34	188.80
	Research spaces	m^2/person	1451.18	1450.54	1444.47	1482.87
Output	Students (teaching)	person	14836.84	16665.30	14037.56	13453.39
	Job rate (teaching)	%	85.86	86.31	87.69	87.33
	Student income (teaching)	Million dong	5.54	5.81	6.13	6.17
	ISI/Scopus paper (academic)	1	20.73	25.86	30.73	36.40
	Other scientific outcome (academic)	1	2385.86	1383.21	868.74	636.01
	Observation		70	70	70	70

Source: Authors

Appendix 2: TFP and its decompositions based on the input-oriented approach

TFP (aggregated efficiency) and its decompositions are calculated as follows:

$$\begin{aligned}\underbrace{TFPE}_{Performance\ efficiency} &= \underbrace{TFP}_{Total\ Factor\ Productivity} : \underbrace{TFP*}_{Maximum\ of\ TFP\ given\ period\ t} \\ &= \underbrace{ITE}_{Input-oriented\ technical\ efficiency} \times \underbrace{ISME}_{Input-oriented\ scale-mixed\ efficiency} \\ &= ITE \times \underbrace{ISE}_{Input-oriented\ scale\ efficiency} \times \underbrace{RME}_{Residual\ of\ mixed\ efficiency}\end{aligned} \tag{3}$$

Consider a set of n =1,…, *N* public universities and t=1,…, *T* periods of time. Each public university uses $x \in \mathbb{R}_+^K$ inputs to produce

$y \in \mathbb{R}_{+}^{Q}$ outputs. Following O'Donnell's approach (2012a, 2012b), the TFP is defined as the ratio of aggregate output to aggregate input. Mathematically, TFP is represented by

$$TFP_{nt} = \frac{Y(y_{nt})}{X(x_{nt})} \tag{4}$$

where, $Y(y_{nt})$ and $X(x_{nt})$ are the aggregate output and input. Y(.) and X(.) are aggregator functions with y_{nt} and x_{nt} as output and input vectors. The FP index defined by O'Donnell (2014) is used for aggregator functions Y (.) and X(.), as follows:

$$\begin{aligned} &Y(y) = D_0(\bar{x}, y, \bar{t}) = \min\left(p > 0 \ : x \, can \, produce \frac{y}{p} in \ the \ period \ \bar{t}\right) \\ &and \\ &X(x) = D_I(x, \bar{y}, \bar{t}) = \max\left(p > 0 \ : \frac{x}{p} can \ produce \ y \ in \ the \ period \ \bar{t}\right) \end{aligned} \tag{5}$$

Where, $\bar{x}$ and $\bar{y}$ are reference values of input and output given a representative period $\bar{t}$. In this case (comparisons are to be made between all T observations in the data set), FP is used to calculate the average quantities of inputs and outputs for the reference values, i.e., $\bar{x} = \{\bar{x}_i\}_{i=1}^{N}$ and $\bar{y} = \{\bar{y}_i\}_{i=1}^{N}$, with $\bar{x}_i = \Sigma_{t=1}^{T} x_{it}/T$ and $\bar{y}_i = \Sigma_{t=1}^{T} y_{it}/T$.

TFP* is the point reaching maximum TFP in given period t. To illustrate the decomposition in Eq. (1), Fig. 2 reports all potential combinations of aggregate output and input. There, the slopes of OA and OE are TFP and TFP*, respectively. The ratio between the OA and OE slopes is the total productivity efficiency of public university A.

Farrell (1957) introduced the notion of input-oriented technical efficiency (ITE) to measure the maximum achievable TFP using minimum aggregated inputs while holding input and output mixes fixed. In Fig. 2, ITE is the ratio between the slope of OA and OB. ISE is input-oriented scale efficiency as measured by the ratio of ITE under the constant returns to scale (CRS) assumption to ITE under the variable returns-to-scale (VRS) assumption ($ISE = \frac{ITE_{CRS}}{ITE_{VRS}}$). In other words, ISE measures the increased TFP in a public university by moving from the mix-invariant production frontier to its corresponding constant returns-to-scale. Input quantities, and thus aggregate input, will be reduced to reach the straight line, which is tangential to the mix-invariant production frontier (line OF in Fig. 2), i.e., achieving CRS but holding constant the input mix. ISE is the ratio between the slope of OB and OG.

Finally, that efficiency moves from point G to point D in Fig. 2 is due to misallocation in the input mix. Indeed, we compare aggregate inputs belonging to two production frontiers with CRS but differing by the assumption of the presence or absence of invariance in the input mix. Then, RME is equal to the ratio of the slope of OG to the slope of OD.

Thus, change in university efficiency n^{th} between t_1 and t_2 stages can be defined as follows:

$$TFP_{n,t_1,t_2} = \underbrace{\left(\frac{TFP_{t_2}^{*}}{TFP_{t_1}^{*}}\right)}_{dTECH} \times \underbrace{\left(\frac{ITE_{n,t_2}}{OTE_{n,t_1}}\right)}_{dITE} \times \underbrace{\left(\frac{ISE_{n,t_2}}{ISE_{n,t_1}}\right)}_{dISE} \times \underbrace{\left(\frac{RME_{n,t_2}}{RME_{n,t_1}}\right)}_{dRME} \tag{6}$$

Based on previous research (e.g., Tran and and Villano, 2017), four inputs and five outputs are selected for calculating efficiency and its decompositions. The four inputs include the number of lecturers with PhDs, lecturers with master's degrees, administrative staff, and research space. The five outputs include (1) the number of scientific publications in ISI/Scopus journals, (2) other domestic scientific activities, (3) enrolled students, (4) student employment rate after 12 months and (5) student income.

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