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Water productivity is in the eye of the beholder: benchmarking the multiple values produced by water use in the Phoenix metropolitan area

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Abstract. Water productivity (or efficiency) data inform water policy, zoning, and planning, along with water allocation decisions under water scarcity pressure. This paper demonstrates that different water productivity metrics lead to different conclusions about who is using water more effectively. In addition to supporting the population's drinking and sanitation needs, water generates many other public and private social, environmental, and economic values. For the group of municipalities comprising the Phoenix metropolitan area, we compare several water productivity metrics by calculating the water value intensity (WVI) of potable water delivered by the municipality to its residential and non-residential customers. Core cities with more industrial water uses are less productive by the conventional efficiency measure of water used per capita, but core cities generate more tax revenues, business revenues, and payroll per unit of water delivered, achieving a higher water productivity by these measures. We argue that policymakers should consider a more diverse set of socio-economic water productivity measures to ensure that a broader set of values are represented in water allocation policies.

1 Introduction

The coming decades will see major challenges in meeting demands for water in the United States and across the globe (Postel et al., 1996; Devineni et al., 2015). Apportioning water effectively between agriculture, the world's largest water user, and the water use of industry, energy, and urban development will become increasingly important (Hoekstra, 2014; Vörösmarty, 2000; Gleick and Palaniappan, 2010). Reliable metrics are needed for informed decision-making about allocating water sustainably, equitably, and optimally. This is especially true in water-scarce regions like the American Southwest (Tidwell et al., 2012; Wildman and Forde, 2012; Schewe et al., 2014). However, in such regions, there is often a limit to how much water cities can reduce through conservation measures or other demand management policies – a phenomenon known as "demand hardening". Even if conservation is still producing water efficiency gains decoupled from growth to date (Richter et al., 2020), demand will eventually harden, so it is in the public's interest to allocate water based on the merit and benefit of use (Howe and Goemans, 2007), however merit and benefit might be defined.

Careful management of freshwater is especially important for the municipalities comprising the Phoenix metropolitan statistical area (Phoenix MSA or PMA), Arizona (Gober et al., 2010, 2013; Rushforth and Ruddell, 2015). With a population of 4.9 million, in 2019 Phoenix–Mesa–Chandler was the 10th most populous metropolitan area in the country (U.S. Census Bureau, 2020). Economic growth has been tightly coupled with population growth in the PMA. In 2017 the GDP for the Phoenix MSA was close to USD 217 billion, having grown by 30 % between 2010 and 2018 (U.S. Bureau of Economic Analysis, 2019). Underlying the Phoenix MSA's population growth and economic growth are increasingly scarce water resources.

Studies of water use often employ variations of water footprint analysis to measure water use or water use efficiency (Hoekstra et al., 2011, 2015; Marston et al., 2018; Paterson et al., 2015; Rushforth and Ruddell, 2018). Water footprints have been calculated for cities in the United States (Paterson et al., 2015) and even specifically for cities in Arizona (Bae and Dall'Erba, 2018; Rushforth and Ruddell 2015, 2016; Scott and Pasqualetti, 2010). Water productivity studies have been conducted on industries and products (Marston et al., 2020; Evenson et al., 2018; Maupin et al., 2014; Mayer et al., 2016; Blackhurst et al., 2010; Solley et al., 1983), on the electric power grid (Ruddell et al., 2014), and on Arizona semiconductors (Hubler et al., 2012), in addition to the more common study of irrigation agricultural water productivity (Xu et al., 2019; Kijne et al., 2003; Hamdy et al., 2003). Water efficiency benchmark data can help policymakers to develop and implement sound water policy (Berg, 2010). Such benchmarks can help stakeholders to quantify progress towards policy objectives and can help regulators fine-tune efficiency goals (Haider et al., 2016).

Per the logic of Embedded Resource Accounting (Rushforth et al., 2013; Ruddell et al., 2014), produced values are accounted for differently by different parties because these parties have different worldviews and decision boundaries by which they account for internal and external costs and benefits. For instance, revenue is mostly valued by business owners, payroll (total salaries) is mostly valued by workers (and is a cost to business owners), taxes are mostly valued by the branch of government collecting the specific tax and by the public beneficiaries of this tax revenue (e.g., state income tax to the state, property tax to the municipality), and population is valued by (presumably) all people – but most especially by democratically elected government officials who set water policy because people vote. There are also many other social, environmental, and economic values produced where water inputs are an input factor (Vardon et al., 2012), including, for instance, aquatic habitat created by outdoor water use in a desert city, urban heat island mitigation, and federal tax revenue. The return of revenue directly to a water department responsible for its provision is another important type of value needed for fiscal planning and support of water operations (Borrego-Marin et al., 2016), but that kind of revenue is of very narrow interest to a single department of a single municipal government and is discounted by other parties. Because there are many social, environmental, and economic stakeholders with many different sets of interests and values, multiple water use efficiency or productivity benchmarks are appropriate to measure the efficacy of water allocation. However, it should be noted that the current study did not include the social, environmental, and full economic value of water due to a lack of available data.

The standard residential water efficiency or water sustainability measure for water utilities in the United States is gallons per capita per day (GPCD). Water use efficiency is the reciprocal of the water productivity. Water productivity – also called water value intensity (WVI; Ruddell et al., 2014) – is a metric expressing the benefits of water use (in units of the benefit) relative to the costs (in units of water use). The goal of water policy should be to do more social, environmental, and economic good with limited water resources but not necessarily to use less water but to maximize the value of scarce resources, which may include conservation measures that allow for the future use of water. Shifting to a water productivity (or WVI) perspective puts the emphasis on the values and benefits that are produced, rather than the water that is saved. For example, if we invert the standard GPCD metric, we obtain people per gallon per day (PPGD), and this makes it clear that such a metric values the support of the additional population using the water resources. It is not incorrect to use an efficiency metric, but we prefer the positive productivity framing to the negative efficiency framing for these reasons.

Comparing multiple water productivity metrics and benchmarks is particularly helpful when there are multiple values and benefits associated with the water use. In this paper we develop a case study comparing multiple water productivity benchmarks for the group of municipalities comprising the Phoenix metropolitan area. For these municipalities we compare the water productivity in units of value produced per acre-foot (ac-ft) of water delivered. Water productivity metrics in this paper's case study include (1) residential population supported, (2) payroll, (3) gross revenue, (4) state income tax, (5) state sales tax, and (6) total property tax. Other productivity metrics could be used such as the water intensity of land use, or we could add more social and environmental value considerations, but these are beyond the scope of this paper's case study due primarily to a lack of data availability. Our research question is as follows: "What is the comparative water productivity of the municipalities of the Phoenix area, using multiple water productivity measures?"

2 Methods

Water that is available to PMA cities is allocated using a complex system of legal water rights and conveyed to the municipalities via large-scale physical infrastructure systems (Jacobs and Megdal, 2004; Holway, 2007). Most PMA municipalities draw water from three main physical water sources: the Colorado River, the Salt–Verde River system, and the large, interconnected groundwater aquifer underlying the metro area. However, while many municipalities have access to all three sources, some municipalities, typically newer ones on the outer edge of the metropolitan area, may not have access to Salt River Project (SRP) or Central Arizona Project (CAP) water (Rushforth et al., 2020).

Within each municipality water is delivered to residential and non-residential uses, which yield residential values (income tax, property tax, population) and non-residential values (payroll, net/gross revenue, sales tax). Of the many municipalities comprising metropolitan Phoenix area, we include 12 in this study (Fig. 1): Apache Junction, Avondale, Buckeye, Chandler, Gilbert, Glendale, Goodyear, Mesa, Peoria, Phoenix, Scottsdale, and Tempe. Smaller and outlying cities (e.g., Litchfield Park, El Mirage, Paradise Valley, Queen Creek, Guadalupe, Surprise, Cave Creek, Fountain

Hills) were omitted due to a lack of data at the time of analysis.

Water use studies may be based on consumption or withdrawal accounting. However, in this study area water withdrawal is equal to water consumption, so we have simplified the language to water use, which is defined as the total volume of water delivered in a municipality less loss and unaccounted (LandU) for water. This is the right choice for most water use studies per the arguments in Ruddell (2018) because city water resources, infrastructure, operating costs, and water rights are measured and priced in units of water volumes delivered, not in terms of net hydrological water balances. We use acre-feet units for this study, not SI units, because acre-feet is the unit of measurement used and understood throughout the water management community in the United States, and converting to SI units renders the results more difficult for use in policy applications. Reclaimed water use was not included in this study since it is not delivered to municipalities by an external agency and because it is not withdrawn from the three major hydrological water sources of the region. Also, we do not consider the indirect value of reclaimed water because the reclaimed water uses, such as recreational turf irrigation, make it difficult to measure associated economic value. Additionally, reclaimed water (unlike potable water) is subject to varied city and county policies and standards for reporting and accounting, making it difficult to compare reclaimed water data robustly between municipalities.

This paper's "value intensity" water productivity metrics relate gross value output to gross water input, including the residential population supported by potable water deliveries, gross revenues, payroll, state sales tax, state income tax, and property taxes. Water productivity could be calculated using a range of metrics, to include, for example, different social and environmental benefits of a city's water use, the marginal product (instead of gross), or the complete Scope $1+2+3$ indirect supply chain water use (instead of Scope 1). Also, these multiple value metrics could be weighted to assign differential importance if appropriate. Because this is the first study of its kind, we calculate a simple set of metrics that are readily computable and straightforward to explain (Table 1), and we weight the metrics equally in the figures for simplicity of visual comparison. Note that payroll and taxes are two components of gross revenue and as such are not independent from gross revenue.

2.1 Data sources

This study uses older data from the calendar year 2007 due to data availability constraints. The specific variety of data for residential and non-residential water use was no longer collected by the State of Arizona after 2009. We chose 2007 because this is the most recent pre-2009 year coinciding with the publication of the US Economic Census.

Table 1. General characteristics of cities in the PMA statistical area (* no reclaimed water). NA – not available

City	Population	Area (km^2)	Density (pop km^2)	Payroll (USD ×1000)	Gross revenue (USD ×1000)	Total property tax (USD ×1000)	Income tax (USD ×1000)	Sales tax (USD ×1000)	Total water use* (ac-ft)	Acre-feet per km^2 of city	Acre-feet per person per km^2
Apache Junction	32 901	91	362	3364	42 344	NA	108	2795	10 244	759	28
Avondale	78 043	119	656	7534	129 608	5 883	241	8554	12 119	689	18
Buckeye	37 678	971	39	990	20 512	3 186	32	1354	4989	34	129
Chandler	242 522	166	1460	80 685	987 115	33 616	2582	64 150	23 501	945	16
Gilbert	204 904	166	1234	32 876	330 022	22 258	1052	21 782	44 335	1782	36
Glendale	249 455	155	1609	48 376	521 636	28 557	1548	34 428	69 359	2994	44
Goodyear	53 654	495	108	8702	85 775	10 805	278	5661	11 169	150	104
Mesa	459 742	352	1306	133 398	1 121 299	NA	3628	74 006	105 459	2002	80
Peoria	152 795	451	339	28 945	445 973	23 529	926	29 434	51 437	764	153
Phoenix	1 536 632	1339	1148	700 624	6 504 679	266 891	22 420	429 809	377 341	1891	329
Scottsdale	233 105	477	489	188 927	1 750 749	50 838	6046	115 549	109 065	1536	223
Tempe	172 589	104	1660	138 748	1 658 540	31 736	4439	109 463	70 907	4600	41

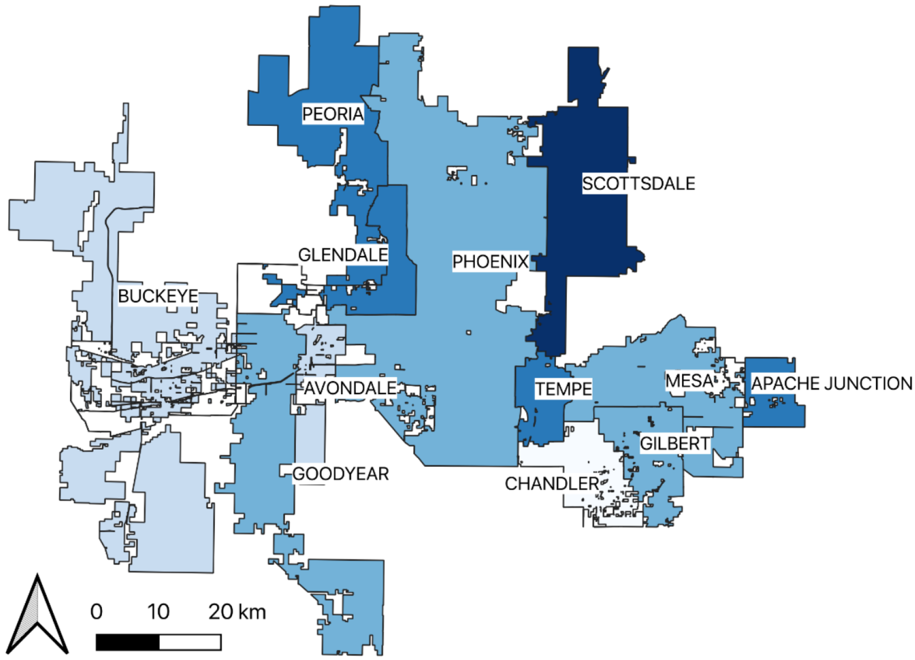

Figure 1. Map of the Phoenix metropolitan statistical area (PMA) showing the member municipalities.

Residential and non-residential water use data for the PMA's municipalities in this study were obtained from the Arizona Department of Water Resources Imaged Records. Reported water use data for 2007 were used to match US Economic Census data for the same year. Specifically, water use data contained in this report are found in ADWR notifications on gallons per capita per day (GPCD) and lost and unaccounted (LandU) for water sent to the individual cities studied in this report (Arizona Department of Water Resources, 2011a–i). LandU water was incorporated into this study by attributing LandU water proportionately to total water use by residential and non-residential sectors (for an example see Appendix A and the equation in Appendix B).

Income data were obtained from the U.S. Census Bureau (2009a–f). Property tax data were obtained from the annual budgets from each of the cities in the study (City of Chandler, 2008, 2009; City of Glendale, 2008; City of Goodyear, 2007; City of Mesa, 2008; City of Peoria, 2007; City of Phoenix, 2007; City of Scottsdale, 2008; City of Tempe, 2007; Town of Avondale, 2010; Town of Buckeye, 2007; Town of Gilbert, 2007). Manufacturing, retail, information services, real estate, and professional and technical services data were obtained from the 2007 Economic Census (U.S. Census Bureau, 2009a–f). See Appendix C for the full economic data used in this study.

Water value intensities (WVIs) were calculated using the water-volume weighted averages of residential and non-residential sectors (Table D1). Economic values on a water use basis were analyzed for several economic categories in the US Economic Census: city-level or town-level income data (Tables D2, D3), city- or town-level manufacturing (Tables D4, D5), city- or town-level retail data (Table D6), city- or town-level information services (Table D7), city- or town-level real estate data (Table D8), and city- or town-level professional and technical services (Table D9).

2.2 Simplified Embedded Resource Accounting: point of view matters in water use accounting

This analysis employs a simplified version of Embedded Resource Accounting (ERA; Ruddell et al., 2014) to associate indirect and direct values with direct (Scope 1) and indirect (Scope 2+3) impacts in an input-output network. In this case there are direct and local values produced (e.g., Tables D1–D9) and direct impact on the local freshwater stock, and indirect values and impacts are neglected. The water use metrics in this paper are therefore calculated from the point of view of a hypothetical manager of the water resources of the Phoenix metropolitan area (PMA), who is interested in maximizing a diverse basket of values that are directly associated with water use processes in the PMA. The same hypothetical manager is therefore also disinterested in indirect value creation and impact such as federal tax revenues or the water impacts of the PMA's supply chains lying outside the area. Everything inside the PMA is "internal", and everything outside the PMA is "external" from this hypothetical manager's point of view. We assert that this point of view is historically responsible for water allocation decisions and regulations for the PMA and resembles the point of view of the Governor's office, the regional government, or the Arizona Department of Water Resources, so this is an appropriate choice for this study. Because the worldview of this hypothetical manager encompasses the metro area, ERA defines the resource stock of interest as the total combined annual water deliveries from the CAP, the SRP, and groundwater resources to the PMA's major municipalities individually and collectively. If a different point of view is chosen for the accounting, the results will change. For example, the business owners of the City of Tempe internalize revenue-generating value but not necessarily other values like payroll or taxes benefitting the City of Tempe and its labor force.

The direct water value intensity $\mathrm{WVI}_{x,l}$ used here is simply the ratio of the value (V) of type (l) produced as an output of the municipality's (x) collective processes to the input of water (W) to the municipality's processes. In other words, $\mathrm{WVI}_{x,l}$ is the ratio of value out to water in. $\overline{\mathrm{WVI}_l}$ is the mean WVI for value l for all municipalities in the area. $\mathrm{WVI}^n_{x,l}$ has been normalized (n) by dividing $\mathrm{WVI}_{x,l}$ by the mean $\overline{\mathrm{WVI}_l}$, such that municipalities with results above 1 have above-average WVI for that value type. BWVI_x is the basket-weighted water value intensity for municipality x; it is the weighted average across all value types for that municipality. In this study, we assume weights of 1 for all value types. From this point of view, all six types of value assessed here are weighted equally. $\mathrm{BWVI}_x{}^n$ is the normalized value, like $\mathrm{WVI}^n_{x,l}$ above.

WVIs may include economic data and measures of economic value, but a WVI – or any VI – is not a price or a measure of marginal value, product, or cost according to the classical economic theory of value because it does not consider the marginal contribution of the impact on the resource stock to the production of values, the cost of the resource, or the value added by the process. Since VIs are not prices or costs, they may not be added together to directly measure the value produced by a process. Rather, VIs should be interpreted as multiple independent benchmarks of the gross productivity of the water use. The WVI presented here is similar to the water productivity definition based on a single factor of production using water per Kumar (2021). In other words, WVI is similar to the partial factor productivity (PFP), which is a ratio of a measure of total output to a measure of a single input category. The two differences are technicalities and are that (a) WVI could include indirect value production, and (b) WVI makes no attempt to use total productivity and instead is calculated several times using several different and non-commensurable productivities (i.e., values). Gross WVI is a disambiguated metric that is a precise subtype of gross water productivity metric, per the ERA mathematics.

2.3 Residential sector water value intensities

Property taxes were used as a measure for the values produced by residential water use. Primary, secondary, and total levied property taxes by municipalities were considered in this analysis. Calculation of the value intensity of residential water on a per-volume use basis is shown in Appendix A.

2.4 Non-residential sector water value intensities

City-level net and gross revenues and payrolls were used as a measure for the values produced by non-residential water uses such as commercial, industrial, and governmental uses of the city's potable water supplies. City-level state sales tax contributions and income taxes paid to the state were estimated for the non-residential sector using the gross revenue and payroll data, respectively. The state sales tax rate was set at 6.6 % and the income tax rate 3.3 %, per statutes in effect in Arizona during the study period. From these data, the value intensity of non-residential water uses was calculated for city-level net and gross revenues, payroll, state sales tax contribution, and income taxes paid to the state. Note that income tax is considered a value product of the non-residential sector in this analysis, and taxed payroll is a value product of the business sector, not the residential sector. Net and gross revenue and payroll data were obtained from the US Economic Census. Population data were obtained from the U.S. Census Bureau (2007). Equations for revenue, payroll, and tax VIs follow. Calculation methods are shown in Appendix A.

3 Results

In terms of residential population supported per acre-foot of water used (Fig. 2), outlying cities such as Buckeye, Goodyear, and Avondale are more productive (or efficient) than core cities like Phoenix, Tempe, and Scottsdale. However, when economic productivity measures are considered (Fig. 3), core cities like Phoenix, Tempe, and Scottsdale dominate the rankings because they produce far more payroll, tax, and business revenue per gallon of water used.

4 Discussion

Each city has its own unique water value profile (Table 1) which contributes to its water productivity profile. For example, Chandler is the fourth largest city in the PMA by population and had the fourth lowest normalized WVI per capita, but its normalized WVI for gross revenue is well above the PMA average (Fig. 3). Chandler has a disproportionately large industrial sector dominated by high-value semiconductor manufacturing products and services. Previous studies have found this sector produces an unusually large amount of economic value relative to use of water (Hubler et al., 2012). Figure 3 reveals tradeoffs between multiple normalized water productivity objectives. For example, there is a tradeoff between WVI for gross revenue and WVI for population. The relatively higher the business revenue a community generates with its water, the relatively lower the population it supports with its water. A detailed study of the Pareto frontiers and tradeoffs between these multiple objectives is beyond the scope of this paper, but such a tradeoff appears

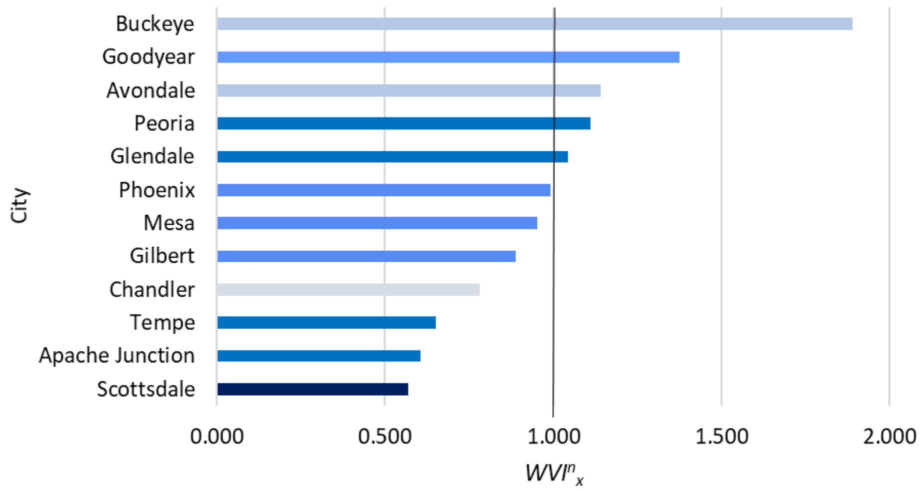

Figure 2. PMA municipalities x listed in order of their relative WVI_x^n for residential population supported. The PMA's mean value is 1. Outlying bedroom communities like Buckeye, Goodyear, and Avondale score above average on the traditional per-capita basis of water use benchmarking (cities are color-coded to correspond with Fig. 1).

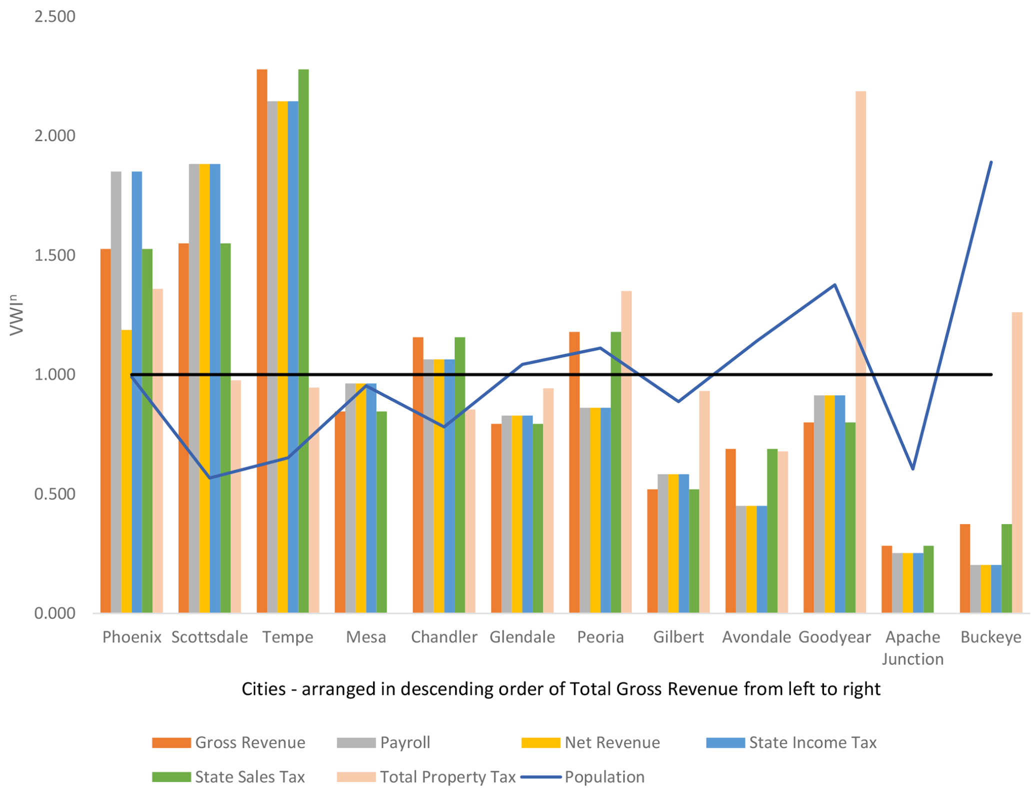

Figure 3. WVI^n for economic value types (colored bars) and population value type (blue line) for each PMA municipality. The PMA's mean value is 1 (black). Municipalities are arranged in order of decreasing tax revenues from left to right. This ranking also corresponds approximately with geographic distance from the overall urban center of Phoenix and to size of population and economic GDP. Core municipalities like Tempe, Scottsdale, and Phoenix score above average on an economic basis of water use benchmarking but below average on a population basis of population supported, demonstrating some degree of tradeoff between these productivity objectives.

to have emerged within the PMA. Despite this, the standard US measure of water efficiency, gallons per capita per day (GPCD; Evenson et al., 2018), implies that water's value lies entirely in supporting residents and their swimming pools and lawns. When applied in isolation from other metrics for other objectives, this standard measure favors allocating water to bedroom communities. But this comes at a cost of the jobs and tax revenues that the residents of those bedroom communities need for their livelihoods and to pay for their water rights and water infrastructure.

Because cities, state government, and economic development organizations want to promote high-quality economic development, and the City of Chandler uses much of its water for this kind of economic activity, allocating more water toward Chandler as compared with a bedroom community would seem to merit consideration based on economic water productivity benchmarks. After all, a bedroom community's residents need the payroll and tax revenues produced by companies in the City of Chandler. But, in turn, those companies employ the workforce that lives in the bedroom communities and depend on that labor for their operations. A residential population cannot be supported without jobs and revenues; both values matter, and each supports the other. Therefore, a more diverse set of water productivity benchmarks can help decision makers understand the tradeoffs involved in their allocation of water to different kinds of cities and can help policymakers avoid undervaluing the economic allocations of water that are needed to support employment for the residential population. Additionally, the tax base is the major constraint on the ability of a city to finance water rights and water infrastructure to provide adequate water for its residential population. Linking economic and population growth is important. There have been several advocates for the concept of "wet growth" (Arnold, 2005) and water-conscious land use planning (Bates, 2012). Water-conscious economic planning and growth can help to promote, protect, and restore water sources and can prevent growth beyond the limits of water resources (Gober et al., 2010; Larson et al., 2013; Li et al., 2016).

Accurate estimation of the water resources required to "build out" the municipality's zoning and master plan is a crucial part of this land use planning process (Gober et al., 2010, 2013; Larson et al, 2013; Li et al., 2016). Once land is allocated to a use (i.e., zoned), the water and land associated with that use cannot be reallocated easily or inexpensively, if at all (Marston and Cai, 2016). In addition, as a municipality continues to grow, it typically approaches the "build-out" stage where further changes become prohibitive due to the scarcity and depletion of land and water resources. Balancing various water productivity values is therefore important in the land use planning process before development occurs.

We present results that focus narrowly on economic water productivity in the PMA as an alternative to GPCD as an efficiency metric, but it is preferable to also include broader economic, environmental, and social dimensions of water productivity. For example, urban tree and shade programs, which are water consumers, may not have high economic water productivity or generate tax revenue, but they do produce demonstrable ecological service benefits such as shade, mitigation of air pollution, flood amelioration, and reduced urban heat island effects. Water planners and decision makers do not apply equal weighting to their multiple values, so any stakeholder would have their own weights to apply to the multiple-objective decision process that is implied by the use of multiple water productivity metrics. Additionally, combining indirect water use analysis (Rushforth and Ruddell, 2015) with the present paper's multiple value analysis will provide a complete evaluation of the value created by a municipality's water use, but it is outside the scope of this work. We think it is important to develop a clear presentation of the multiple-value argument first, and on its own merits, before adding the complexity of indirect value creation from water use.

When broader values like revenue, payroll, and tax benefits are factored into water allocation decisions, different water allocation decisions could emerge. These are political and value-based decisions, not engineering decisions, but such decisions should be more broadly informed with a broader set of water productivity benchmarks.

5 Conclusions

This study finds that bedroom communities show higher water productivity based on the standard efficiency benchmark of gallons per capita, but core cities which host large businesses show higher water productivity using a basket of economic values like taxes, payroll, and business revenues. There may be tradeoffs between these competing values produced by water use, and different decision makers bring different points of view and value weighting to that policy discussion. A broader basket of water productivity benchmarks could inform more balanced and equitable water allocation decisions by policymakers.

Appendix A: Detailed VI equations

The VI of residential water ($VI_{\text{Property Tax}}$) was measured on a per-volume use basis using property taxes by dividing the amount of levied property taxes by the municipality's volume of water delivered to residential uses. Property tax data in Appendix C were obtained from the Maricopa County Department of Finance (2009). For some cities, property taxes were reported as zero due to city-specific policies that restrict the ability of the city to collect property tax.

$$VI_{\text{property tax}} = \frac{\text{USD levied property tax}}{\text{volume}_{\text{H}_2\text{O}}\text{residential}_i \text{ (ac-ft)}}$$

Per-capita water use by the residential water use sector of a municipality $VI_{\text{population}}$ is calculated as shown in Eq. (13).

This metric is included because per-capita equity in water use is currently the primary type of value intensity utilized for water allocation decisions.

$$\mathrm{VI}_{\text{population}} = \frac{\text{population}}{\text{volume}_{\mathrm{H_2O}}, \text{residential}_i \text{ (ac-ft)}}$$

Data in Appendix C were used to calculate the VIs for net and gross revenue, payroll, sales tax, and income taxes using the following equations.

$$\mathrm{VI}_{\text{revenues}} = \frac{\text{USD revenues}}{\text{volume}_{\mathrm{H_2O}}\text{non-residential}_i \text{ (ac-ft)}}$$

$$\mathrm{VI}_{\text{payroll}} = \frac{\text{USD payroll}}{\text{volume}_{\mathrm{H_2O}}\text{non-residential}_i \text{ (ac-ft)}}$$

$$\mathrm{VI}_{\text{sales tax}} = \frac{\text{USD gross revenues}_i \times \text{state sales tax rate}}{\text{volume}_{\mathrm{H_2O}}\text{non-residential}_i \text{ (ac-ft)}}$$

$$\mathrm{VI}_{\text{income tax}} = \frac{\text{USD payroll}_i \times \text{state income tax rate}}{\text{volume}_{\mathrm{H_2O}}\text{non-residential}_i \text{ (ac-ft)}}$$

Appendix B: Water data tables B1–B3

Table B1. Reported total water demand for PMA municipalities included in this study.

City	Demand category	Year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Apache Junction	Total	10 627	10 523	11 416	10 983	10 639	11 396	11 251	11 825	11 112	11 144
Avondale	Total	5653	7758	9295	10 040	11 123	9893	13 378	14 185	13 033	13 277
Buckeye	Total	1094	1049	2434	2601	738	751	3028	4135	4363	4277
Chandler	Total	48 969	53 263	55 475	55 657	55 697	58 439	61 070	64 404	63 076	60 773
Gilbert	Total	30 438	32 800	33 984	38 047	36 596	40 190	50 515	47 915	49 085	46 239
Glendale	Total	49 472	49 773	51 193	48 707	48 828	49 242	49 740	46 849	49 586	48 133
Goodyear	Total	2570	3309	3555	4243	5307	6328	6409	8088	8163	8289
Mesa	Total	101 461	102 935	97 180	100 458	95 933	100 363	100 203	100 027	93 317	89 794
Peoria	Total	24 602	21 503	22 593	21 715	22 656	25 421	27 659	28 527	28 717	27 288
Phoenix	Total	332 038	340 870	346 226	329 939	337 412	314 314	331 174	321 476	304 153	305 124
Scottsdale	Total	79 479	78 165	84 508	77 901	74 426	80 772	84 427	85 249	84 051	83 444
Tempe	Total	63 236	61 729	60 223	58 526	57 644	53 515	52 201	54 915	50 239	49 682

Table B2. Reported residential water demand for PMA municipalities included in this study.

City	Demand category	Year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Apache Junction	Residential	4701	4917	5387	5605	5678	5804	6059	6059	6059	5761
Avondale	Residential	4835	5481	6119	6483	7175	7093	8362	8362	8832	8715
Buckeye	Residential	581	604	679	622	599	643	1617	1617	1617	2629
Chandler	Residential	27 488	29 152	31 316	31 599	32 465	33 906	35 539	35 539	34 424	34 766
Gilbert	Residential	19 816	21 702	23 905	24 647	25 633	27 110	28 684	28 684	28 684	30 910
Glendale	Residential	35 135	34 667	36 044	34 348	34 427	33 567	34 660	34 660	34 660	31 457
Goodyear	Residential	1335	1640	2006	2430	3086	3481	3883	3883	3883	4397
Mesa	Residential	64 242	65 180	67 026	65 655	65 890	63 972	65 319	65 139	65 139	60 494
Peoria	Residential	14 400	15 208	17 077	16 925	16 962	16 224	18 981	18 981	18 981	18 819
Phoenix	Residential	208 431	205 247	209 018	201 214	195 013	195 013	202 387	202 387	202 387	188 503
Scottsdale	Residential	49 659	49 370	52 737	51 083	54 719	54 719	57 401	57 401	57 401	56 568
Tempe	Residential	29 814	30 826	31 884	27 593	25 989	25 989	26 208	26 208	26 209	25 024

Table B3. Reported non-residential water demand for PMA municipalities included in this study.

City	Demand category	Year									
		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Apache Junction	Non-residential	5419	5137	5585	5183	4741	5145	5048	5048	5048	4748
Avondale	Non-residential	2305	2150	2866	2821	3118	1983	4097	4097	3846	4060
Buckeye	Non-residential	301	188	848	1788	106	110	1270	1270	1270	1482
Chandler	Non-residential	18 149	19 936	20 795	20 126	19 164	20 259	22 043	23 635	23 316	21 739
Gilbert	Non-residential	6503	8354	8030	9244	9679	9995	11 585	11 585	11 585	11 929
Glendale	Non-residential	10 595	11 521	12 351	11 311	11 013	10 797	12 965	12 965	12 965	12 135
Goodyear	Non-residential	1156	1668	1486	1730	2199	2959	2756	2756	2756	3442
Mesa	Non-residential	27 053	36 579	29 500	29 028	29 252	26 898	29 373	29 373	29 373	27 340
Peoria	Non-residential	4923	4334	3890	3539	4183	5573	7248	7248	7248	7449
Phoenix	Non-residential	102 683	102 182	105 805	100 008	101 098	106 018	109 194	109 194	109 194	102 979
Scottsdale	Non-residential	18 730	20 071	18 740	16 140	25 392	21 305	23 725	23 725	23 725	21 274
Tempe	Non-residential	27 656	26 117	24 887	25 396	25 343	23 811	24 392	24 392	24 392	22 761

Appendix C: Tax data tables C1

Table C1. 2007 payroll and gross revenue for PMA municipalities included in this study.

	Economic characteristics		
City	Population	Payroll	Gross revenue
Tempe	172 589	USD 138 748 352	USD 1 658 540 928
Phoenix	1 536 632	USD 700 624 288	USD 6 504 679 434
Chandler	242 522	USD 80 685 664	USD 987 115 338
Scottsdale	233 105	USD 188 927 232	USD 1 750 749 924
Mesa	459 742	USD 113 398 176	USD 1 121 299 146
Surprise	87 488	USD 7 421 120	USD 85 960 050
Avondale	78 043	USD 7 534 432	USD 129 608 292
Peoria	152 795	USD 28 945 632	USD 445 973 946
Gilbert	204 904	USD 32 876 480	USD 330 022 770
Glendale	249 455	USD 48 376 608	USD 521 636 346
Apache Junction	32 901	USD 3 364 128	USD 42 344 016
Buckeye	37 678	USD 990 176	USD 20 512 800

Table C2. 2007 tax data for PMA municipalities included in this study.

	Taxes collected			
City	State income tax paid (USD 1000s)	Primary property tax paid (USD 1000s)	Secondary property tax paid (USD 1000s)	State sales tax paid (USD 1000s)
Tempe	4440	10 371	21 365	109 463 701
Scottsdale	6046	21 166	29 673	115 549 495
Phoenix	22 420	103 664	163 227	429 308 843
Peoria	926	3002	20 527	29 434 280
Chandler	2582	8506	25 109	65 149 612
Mesa	3629	–	–	74 005 744
Goodyear	278	4172	6633	5 661 210
Glendale	1548	3888	24 669	34 427 999
Avondale	241	1796	4087	8 554 147
Gilbert	1052	–	27 258	21 781 503
Buckeye	32	2839	347	1 353 845
Apache Junction	108	–	–	2 794 705

Appendix D: Financial data tables D1–D9

Table D1. Water value intensities for PMA cities.

	Phoenix	Scottsdale	Tempe	Chandler	Mesa	Glendale	Peoria	Gilbert	Goodyear	Avondale	Buckeye	Apache Junction	MSA average
Population (people per acre-foot)	4.78	2.73	3.14	3.77	4.60	5.03	5.36	4.28	6.63	5.50	9.11	2.92	4.82
Total taxes paid (DH)	718 620 346	172 433 616	145 639 757	101 347 231	77 634 485	64 533 522	53 890 034	50 091 100	16 744 671	14 678 679	4 571 411	2 902 357	121 036 774
Total taxes (USD per acre-foot) DH	2235	2023	2652	1574	776	1301	1889	1045	2070	1035	1106	257	1610
Payroll (USD per acre-foot)	2179	2216	2527	1253	1134	976	1015	686	1076	531	239	298	1177
Gross revenue (USD per acre-foot)	20 234	20 537	30 202	15 327	11 210	10 520	15 633	6888	10 605	9137	4961	3752	13 250
State income tax (USD per acre-foot)	70	71	81	40	36	31	32	22	34	17	8	10	38
Primary property tax (USD per acre-foot)	322	248	189	132	0	78	105	0	516	127	687	0	200
State sales tax (USD per acre-foot)	1335	1355	1993	1012	740	694	1032	455	700	603	327	248	875

Table D2. Income data for municipalities in the PMA area (source: US Census Bureau and AZ Department of Revenue).

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson
Population	32 901	78 043	37 678	242 522	204 904	249 455	53 654	459 742	152 795	1 536 632	233 105	87 488	172 589	6989
Household income USD	46 649	69 069	71 177	86 333	84 151	65 769	87 264	63 739	78 677	66 661	106 485	68 704	66 359	41 342
Average FAGI USD	45 569	45 162	48 216	63 336	67 378	485 884	62 050	47 815	58 290	50 734	103 539	49 775	52 168	39 084
Per-capita FAGI USD	23 115	18 332	18 785	29 647	28 504	21 643	26 471	21 871	26 943	22 341	55 155	25 436	28 510	14 834
Average tax liability USD	1039	952	1010	1670	1703	1159	1388	1141	1372	1382	3960	1014	1401	807
Tax liability per return USD	804	769	816	1393	1418	919	1157	908	1126	1077	3100	790	1148	643
State transaction and privilege tax distribution to cities USD (2004)	2 661 210	3 001 578	710 766	14 770 829	9 176 047	18 303 410	1 581 887	33 254 566	9 064 543	110 504 126	16 956 076	2 580 405	13 268 827	416 070
State sales tax per capita USD	81	38	19	61	45	73	29	72	59	72	73	29	77	60
State transaction and privilege tax distribution to cities USD (2011)	2 618 154	2 618 154	2 112 351	17 695 102	13 789 266	1 843 879	3 661 678	34 220 312	10 673 717	112 704 366	1 7843 974	6 946 254	12 656 738	497 422

Table D4. Manufacturing data for municipalities in the PMA area (source: US Census Bureau). NA – not available

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson
Population	32 901	78 043	37 678	242 522	204 904	249 455	53 654	459 742	152 795	1 536 632	233 105	87 488	172 589	6989
Manufacturers shipments, 2007 (USD 1000)	NA	0	NA	3 956 031	415 891	912 989	185 496	3 072 462	267 830	16 926 892	4 806 562	NA	5 877 588	2 128 242
Merchant wholesaler sales, 2007 (USD 1000)	24 707	73 438	NA	4 585 919	649 322	1 013 545	NA	2 037 336	251 210	23 670 515	3 445 500	20 359	7 286 114	NA
Retail sales, 2007 (USD 1000)	447 477	1 601 272	215 169	3 608 290	2 079 066	3 627 782	631 710	6 294 523	2 340 433	21 859 505	6 645 363	888 224	6 172 475	138 737
Retail sales per capita (2007) USD	13 756	20 243	5676	14 787	10 063	14 457	11 669	13 669	15 135	14 209	28 447	9878	35 768	19 777
Accommodation and food services sales, 2007 (USD 1000)	36 282	94 636	17 210	500 934	191 244	340 736	105 052	753 178	258 496	3 644 383	1 314 297	115 082	606 835	17 065
Number of establishments	17	NA	9	220	147	135	17	301	56	1946	538	23	511	22
Sales (USD 1000)	24 707	NA	NA	4 585 919	649 322	1 013 545	NA	2 037 336	251 210	23 670 515	3 445 500	20 359	7 286 114	NA

Table D3. Income data for municipalities in the PMA area (source: US Census Bureau and AZ Department of Revenue).

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson
State sales tax per capita USD	79.58	68.57	56.06	72.96	67.29	7.39	68.25	74.43	69.86	73.35	76.55	79.40	73.33	71.17
Sales tax per city area USD	74 826	117 357	5329	274 726	214 055	30 742	19 123	250 790	61 203	218 123	97 020	65 686	316 973	86 508
Sales tax per GPCD USD	10 287	38 703	15 440	108 412	71 564	7448	19 754	167 542	35 609	515 447	42 832	92 569	34 153	5107
Sales tax per ac-ft of water USD	255.58	441.58	364.87	398.03	310.98	26.58	327.83	324.49	207.51	298.68	163.61	942.12	176.20	650.69
Distribution of income tax as urban revenue sharing USD	3 316 127	6 750 611	2 427 836	22 468 783	17 280 849	23 590 446	4 498 039	43 614 424	13 445 840	143 647 008	22 849 062	8 591 077	16 137 384	632 468
Per-capita urban revenue sharing USD	100.79	86.50	64.44	92.65	84.34	94.57	83.83	94.87	88.00	93.48	98.02	98.20	93.50	90.49
Urban revenue sharing per GPCD USD	13 030	48 822	17 745	137 659	89 697	95 287	24 266	213 536	44 857	656 962	54 846	114 488	43 545	6494
Urban revenue sharing per city area USD	94 774	148 040	6470	348 840	268 295	393 305	23 491	319 637	77 098	278 009	124 234	81 239	404 142	109 994
Urban revenue sharing per ac-ft of water USD	323.72	557.03	419.36	505.41	389.78	340.12	402.771	413.57	261.40	380.68	209.50	1165.21	224.66	827.35

Table D5. Manufacturing data for municipalities in the PMA area (source: US Census Bureau). NA – not available

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson
Annual payroll (USD 1000)	1790	NA	NA	291 766	59 745	70 030	NA	174 055	14 834	1 650 697	314 307	3461	722 174	NA
First-quarter payroll (USD 1000)	361	NA	NA	71 408	14 564	16 869	NA	35 616	4002	404 324	75 139	862	156 112	NA
Number of paid employees	66	NA	NA	4198	1450	2079	NA	3372	386	34 585	5811	97	11 117	NA
Operating expenses (USD 1000)	3824	NA	NA	543 461	117 011	141 645	NA	290 320	31 285	2 989 800	664 083	5980	1 201 352	NA
Total inventories, beginning of year (USD 1000)	3200	NA	NA	204 970	49 213	127 262	NA	479 762	16 012	1 655 286	334 508	769	468 771	NA
Total inventories, end of year (USD 1000)	3582	NA	NA	206 196	50 744	133 548	NA	476 581	16 168	1 669 772	361 302	918	499 405	NA
Sales receipts or revenue from administrative records (%)	14 %	0 %	NA	1 %	7 %	17 %	NA	3 %	6 %	4 %	12 %	5 %	4 %	NA
Sales receipts or revenue estimated (%)	0 %	0 %	NA	3 %	13 %	5 %	NA	9 %	4 %	7 %	14 %	37 %	4 %	NA
Sales per establishment (USD 1000)	1453	NA	NA	20 845	4417	7508	NA	6769	4486	12 164	6404	885	14 259	NA
Payroll per establishment (USD 1000)	105	NA	NA	1326	406	519	NA	578	265	848	584	150	1413	NA

Table D6. Retail data for municipalities in the PMA area (source: US Census Bureau). NA – not available

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe
Population	32 901	78 043	37 678	242 522	204 904	249 455	53 654	459 742	152 795	1 536 632	233 105	87 488	172 589
Number of establishments	96	NA	48	694	441	714	109	1507	353	4266	1378	147	847
Sales (USD 1000)	447 477	NA	215 169	3 608 290	2 079 066	3 627 782	631 710	6 294 523	2 340 433	21 859 505	6 645 363	88 224	6 172 475
Annual payroll (USD 1000)	45 386	NA	14 158	353 274	207 222	332 276	61 449	653 862	216 892	1 913 730	664 928	85 661	447 488
First-quarter payroll (USD 1000)	12 047	NA	2830	87 134	48 614	83 526	16 588	164 729	53 154	470 361	163 704	21 606	110 713
Number of paid employees for pay period including 12 March	2181	NA	449	15 714	8466	15 566	2955	28 855	8143	77 534	22 923	4064	16 389
Sales receipts or revenue from administrative records (%)	6 %	0 %	10 %	2 %	2 %	3 %	2 %	6 %	5 %	7 %	4 %	2 %	4 %
Sales receipts or revenue estimated (%)	8 %	0 %	26 %	2 %	4 %	2 %	4 %	6 %	2 %	5 %	5 %	1 %	7 %

Table D8. Information services data for municipalities in the PMA area (source: US Census Bureau). NA – not available

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson
Population	32 901	78 043	37 678	242 522	204 904	249 455	53 654	459 742	152 795	1 536 632	233 105	87 488	172 589	6989
Number of establishments	6	NA	5	77	41	40	8	120	26	694	249	7	162	5
Receipts (USD 1000)	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Annual payroll (USD 1000)	1996	NA	933	104 599	26 622	22 578	D	149 666	9088	1 347 304	541 288	11 593	209 756	D
First-quarter payroll (USD 1000)	492	NA	214	31 879	6502	5956	D	39 598	2390	347 914	134 269	482	54 879	D
Number of paid employees	50	NA	18	2125	454	520	b	3006	252	21256	6725	30	4157	A
Sales receipts or revenue from administrative records (%)	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Sales receipts or revenue estimated (%)	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Table D7. Real estate data for municipalities in the PMA area (source: US Census Bureau). NA – not available

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson
Population	32 901	78 043	37 678	242 522	204 904	249 455	53 654	459 742	152 795	1 536 632	233 105	87 488	172 589	6989
Number of establishments	42	NA	15	301	307	250	61	594	152	2227	1102	55	451	3
Revenue (USD 1000)	23 469	NA	46 949	227 950	185 181	202 866	33 695	524 907	114 499	3 261 013	1 992 041	48 095	768 874	1068
Annual payroll (USD 1000)	3822	NA	2305	37 680	34 687	30 910	5577	80 140	25 124	746 350	335 830	6761	138 486	370
First-quarter payroll (USD 1000)	1024	NA	637	10 260	8767	7560	1201	20 491	6266	185 769	85 047	1653	32 144	77
Number of paid employees	123	NA	58	1171	1003	1208	166	2834	710	17 353	5637	445	3423	12
Sales receipts or revenue from administrative records (%)	12 %	NA	2 %	13 %	11 %	11 %	23 %	15 %	11 %	11 %	9 %	6 %	9 %	39 %
Sales receipts or revenue estimated (%)	11 %	NA	0 %	11 %	8 %	16 %	20 %	13 %	12 %	12 %	8 %	6 %	9 %	0 %

Table D9. Professional and technical services data for municipalities in the PMA area (source: US Census Bureau). NA – not available

City	Apache Junction	Avondale	Buckeye	Chandler	Gilbert	Glendale	Goodyear	Mesa	Peoria	Phoenix	Scottsdale	Surprise	Tempe	Tolleson
Population	32 901	78 043	37 678	242 522	204 904	249 455	53 654	459 742	152 795	1 536 632	233 105	87 488	172 589	6989
Number of establishments	30	NA	22	610	463	303	67	1084	219	5055	1972	83	1005	2
Receipts/revenue (USD 1000)	9679	NA	22 110	373 941	412 515	NA	36 598	709 255	79 141	7 158 437	3 573 147	27 484	13 221 432	NA
Expenses (USD 1000)	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Annual payroll (USD 1000)	2722	NA	7136	490 947	152 162	NA	15 146	302 360	27 912	2 947 465	1 158 253	11 112	606 044	NA
First-quarter payroll (USD 1000)	687	NA	1884	126 119	34 923	NA	3501	69 800	6860	671 593	272 299	3024	152 654	NA
Number of paid employees for pay period including 12 March	122	NA	149	7138	3538	NA	355	7120	702	46 810	17 313	437	10 930	NA
Sales receipts or revenue from administrative records (%)	30 %	NA	2 %	37 %	16 %	NA	16 %	26 %	33 %	15 %	15 %	20 %	15 %	NA
Sales receipts or revenue estimated (%)	21 %	NA	12 %	18 %	6 %	NA	18 %	14 %	8 %	7 %	6 %	22 %	8 %	NA
Annual payroll per establishment USD	91	NA	324	805	329	NA	226	279	127	583	587	134	603	NA

Data availability. The data used in this study are publicly sourced and reproduced in the Appendix of this paper.

Author contributions. BLR designed the study and led the writing. RR carried out data collection and calculations and helped with the writing.

Competing interests. Benjamin L. Ruddell and Richard Rushforth disclose that they were paid consultants to the City of Chandler, Arizona, in 2012.

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